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MILITARY STANDARD

MEASUREMENT OF ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS



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FOREWORD

1. This military standard is approved for use by all Departments and Agencies of the Department of Defense.
2. Recommended corrections, additions, or deletions should be addressed to Aeronautical Systems Division (ENES), Wright-Patterson Air Force Base, Ohio, 45433-6503.
3. This standard contains the general test methods necessary to demonstrate compliance of subsystems and equipment to the requirements of MIL-STD-461. An appendix has been introduced which provides the rationale and background for each paragraph.
4. This standard is designated as revision "D" to coincide with its companion document, MIL-STD-461. Revisions "A," "B," and "C" of MIL-STD-462 were never issued.
5. Substantial changes have been made from previous editions. Some test methods have been eliminated, others significantly changed, and new ones added.
6. A joint committee consisting of representatives of the Army, Air Force, Navy, and Industry prepared this document.

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1. SCOPE

1.1 Purpose. This standard establishes general techniques for use in the measurement and determination of the electromagnetic emission and susceptibility characteristics of electronic, electrical, and electromechanical equipment and subsystems designed or procured for use by activities and agencies of the Department of Defense.

1.2 Application. The testing techniques of this standard are used to obtain data for determination of compliance with the specified MIL-STD-461 requirements. The test methods contained in this document shall be adapted by the testing activity for each application. The adapted test methods shall be documented in the Electromagnetic Interference Test Procedures (EMITP) required by MIL-STD-461.

1.3 Emission and susceptibility designations. The test methods contained in this standard are designated in accordance with an alpha-numeric coding system. Each method is identified by a two letter combination followed by a three digit number. The number is for reference purposes only. The meaning of the individual letters are as follows:

C = Conducted
R = Radiated
E = Emissions
S = Susceptibility

- a. Conducted emissions tests are designated by "CE---."
- b. Radiated emissions tests are designated by "RE---."
- c. Conducted susceptibility tests are designated by "CS---."
- d. Radiated susceptibility test are designated by "RS---."
- e. "---" = numerical order of test from 101 to 199.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

STANDARDS

MILITARY

MIL-STD-461	-	Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility
MIL-STD-45662	-	Calibration Systems Requirements

(Copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, ATTN: NPODS, 700 Robbins Avenue, Philadelphia, PA 19111-5093.)

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

DODISS - Department of Defense Index of
Specifications and Standards

(Copies of the DODISS are available on a yearly subscription basis either from the Government Printing Office for hard copy, or microfiche copies are available from the Director, Navy Publications and Printing Service Office, 700 Robbins Avenue, Philadelphia, PA 19111-5093.)

2.2 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of

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documents not listed in the DODISS are the issues of the documents cited in the solicitation.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

- | | | |
|---------------|---|---|
| ANSI/IEEE 268 | - | Metric Practice. (DOD adopted) |
| ANSI C63.2 | - | Standard for Instrumentation-Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz - Specifications |
| ANSI C63.4 | - | Standard for Electromagnetic Compatibility - Radio-Noise Emissions from Low Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz - Methods of Measurement. |
| ANSI C63.14 | - | Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD). |
| ANSI C95.1 | - | Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields (300 kHz - 100 GHz). |

(Application for copies should be addressed to the IEEE Service Center, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331.)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

- | | | |
|---------|---|--|
| ARP 958 | - | Electromagnetic Interference Measurement Antennas; Standard Calibration Requirements and Methods |
|---------|---|--|

(Application for copies should be addressed to the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

- | | | |
|------------|---|---|
| ASTM E 380 | - | Standard for Metric Practice. (DOD adopted) |
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(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

3. DEFINITIONS

3.1 General. The terms used in this standard are defined in ANSI C63.14. In addition, the following definitions are applicable for the purpose of this standard.

3.2 Acronyms used in this standard.

- a. BIT - Built-in Test
- b. EMI - Electromagnetic Interference
- c. EMITP - Electromagnetic Interference Test Procedures
- d. EMITR - Electromagnetic Interference Test Report
- e. ERP - Effective Radiated Power
- f. EUT - Equipment Under Test
- g. LISN - Line Impedance Stabilization Network
- h. RF - Radio Frequency
- i. RMS - Root Mean Square
- j. TEM - Transverse Electromagnetic
- k. TPD - Terminal Protection Device

3.3 Metric units. Metric units are a system of basic measures which are defined by the International System of Units based on "Le System International d'Unites (SI)", of the International Bureau of Weights and Measures. These units are described in ASTM E 380 and ANSI/IEEE 268.

3.4 Test setup boundary. The test setup boundary includes all enclosures of the Equipment Under Test (EUT) and the 2 meters of exposed interconnecting leads (except for leads which are shorter in the actual installation) and power leads required by the general section of this standard.

4. REQUIREMENTS

4.1 General. General requirements related to test methods, test facilities, and equipment are as stated below. Any approved exceptions or deviations from these general test requirements shall be documented in the EMITP required by MIL-STD-461.

4.1.1 Measurement tolerances. Unless otherwise stated for a particular measurement, the tolerance shall be as follows:

- a. Distance: $\pm 5\%$
- b. Frequency: $\pm 2\%$
- c. Amplitude, measurement receiver: ± 2 dB
- d. Amplitude, measurement system (includes measurement receivers, transducers, cables, and so forth): ± 3 dB
- e. Time (waveforms): $\pm 5\%$

4.2 Shielded enclosures. To prevent interaction between the EUT and the outside environment, shielded enclosures will usually be required for testing. These enclosures prevent external environment signals from contaminating emission measurements and susceptibility test signals from interfering with electrical and electronic items in the vicinity of the test facility. Shielded enclosures must have adequate attenuation such that the ambient requirements of paragraph 4.4 are satisfied. The enclosures must be sufficiently large such that the EUT arrangement requirements of paragraph 4.8 and antenna positioning requirements described in the individual test methods are satisfied.

4.2.1 Radio Frequency (RF) absorber material. RF absorber material (carbon impregnated foam pyramids, ferrite tiles, and so forth) shall be used when performing electric field radiated emissions or radiated susceptibility testing inside a shielded enclosure to reduce reflections of electromagnetic energy and to improve accuracy and repeatability. The RF absorber shall be placed above, behind, and on both sides of the EUT, and behind the radiating or receiving antenna as shown in Figure 1. Minimum performance of the material shall be as specified in Table I. The manufacturer's certification of their RF absorber material (basic material only, not installed) is acceptable.

TABLE I. Absorption at normal incidence.

Frequency	Minimum absorption
80 MHz - 250 MHz	6 dB
above 250 MHz	10 dB

4.3 Other test sites. If other test sites are used, the ambient requirements of paragraph 4.4 shall be met.

4.4 Ambient electromagnetic level. During testing, the ambient electromagnetic level measured with the EUT de-energized and all auxiliary equipment turned on shall be at least 6 dB below the allowable specified limits when the tests are performed in a shielded enclosure. Ambient conducted levels on power leads shall be measured with the leads disconnected from the EUT and connected to a resistive load which draws the same rated current as the EUT. When tests are performed in a shielded enclosure and the EUT is in compliance with MIL-STD-461 limits, the ambient profile need not be recorded in the Electromagnetic Interference Test Report (EMITR). When measurements are made outside a shielded enclosure, the tests shall be performed during times and conditions when the ambient is at its lowest level. The ambient shall be recorded in the EMITR required by MIL-STD-461 and shall not compromise the test results.

4.5 Ground plane. The EUT shall be installed on a ground plane that simulates the actual installation. If the actual installation is unknown or multiple installations are expected, then a metallic ground plane shall be used. Unless otherwise specified below, ground planes shall be 2.25 square meters or larger in area with the smaller side no less than 76 centimeters. When a ground plane is not present in the EUT installation, the EUT shall be placed on a non-conductive surface.

4.5.1 Metallic ground plane. When the EUT is installed on a metallic ground plane, the ground plane shall have a surface resistance no greater than 0.1 milliohms per square. The DC resistance between metallic ground planes and the shielded enclosure shall be 2.5 milliohms or less. The metallic ground planes shown in Figures 2 through 5 shall be electrically bonded to the floor or wall of the basic shielded room structure at least once every 1 meter. The metallic bond straps shall be solid and maintain a five-to-one ratio or less in length to width. Metallic ground planes used outside a shielded enclosure shall be at least 2 meters by 2 meters and extend at least 0.5 meter beyond the test setup boundary.

4.5.2 Composite ground plane. When the EUT is installed on a conductive composite ground plane, the surface resistivity of the typical installation shall be used. Composite ground planes shall be electrically bonded to the enclosure with means suitable to the material.

4.6 Power source impedance. The impedance of power sources providing input power to the EUT shall be controlled by Line Impedance Stabilization Networks (LISNs) for all measurement procedures of this document unless otherwise stated in a particular test method. The LISNs shall be located at the power source end of the exposed length of power leads specified in paragraph 4.8.5.2. The LISN circuit shall be in accordance with the schematic shown in Figure 6. The LISN impedance characteristics shall be in accordance with Figure 7. The LISN impedance shall be measured at least annually under the following conditions:

- a. The impedance shall be measured between the power output lead on the load side of the LISN and the metal enclosure of the LISN.
- b. The signal output port of the LISN shall be terminated in fifty ohms.
- c. The power input terminal on the power source side of the LISN shall be unterminated.

The impedance measurement results shall be provided in the EMITR required by MIL-STD-461.

4.7 General test precautions.

4.7.1 Accessory equipment. Accessory equipment used in conjunction with measurement receivers shall not degrade measurement integrity.

4.7.2 Excess personnel and equipment. The test area shall be kept free of unnecessary personnel, equipment, cable racks, and desks. Only the equipment essential to the test being performed shall be in the test area or enclosure. Only personnel actively involved in the test shall be permitted in the enclosure.

4.7.3 Overload precautions. Measurement receivers and transducers are subject to overload, especially receivers without preselectors and active transducers. Periodic checks shall be performed to assure that an overload condition does not exist.

Instrumentation changes shall be implemented to correct any overload condition.

4.7.4 RF hazards. Some tests in this standard will result in electromagnetic fields which are potentially dangerous to personnel. The permissible exposure levels in ANSI C95.1 shall not be exceeded in areas where personnel are present. Safety procedures and devices shall be used to prevent accidental exposure of personnel to RF hazards.

4.7.5 Shock hazard. Some of the tests require potentially hazardous voltages to be present. Extreme caution must be taken by all personnel to assure that all safety precautions are observed.

4.7.6 Federal Communications Commission (FCC) restrictions. Some of the tests require high level signals to be generated that could interfere with normal FCC approved frequency assignments. All such testing should be conducted in a shielded enclosure. Some open site testing may be feasible if prior FCC coordination is obtained.

4.8 EUT test configurations. The EUT shall be configured as shown in the general test setups of Figures 1 through 5 as applicable. These setups shall be maintained during all testing unless other direction is given for a particular test method.

4.8.1 Bonding of EUT. Only the provisions included in the design of the EUT shall be used to bond units such as equipment case and mounting bases together, or to the ground plane. When bonding straps are required to complete the test setup, they shall be identical to those specified in the installation drawings.

4.8.2 Shock and vibration isolators. EUTs shall be secured to mounting bases having shock or vibration isolators if such mounting bases are used in the installation. The bonding straps furnished with the mounting base shall be connected to the ground plane. When mounting bases do not have bonding straps, bonding straps shall not be used in the test setup.

4.8.3 Wire grounds. When external terminals, connector pins, or equipment grounding conductors in power cables are available for ground connections and are used in the actual installation, they shall be connected to the ground plane after a 2 meter exposed length (see 4.8.5). Shorter lengths shall be used if they are specified in the installation instructions.

4.8.4 Orientation of EUTs. EUTs shall be oriented such that surfaces which produce maximum radiated emissions and respond most readily to radiated signals face the measurement antennas. Bench mounted EUTs shall be located 10 ±2 centimeters from the front edge of the ground plane subject to allowances for providing adequate room for cable arrangement as specified below.

4.8.5 Construction and arrangement of EUT cables. Electrical cable assemblies shall simulate actual installation and usage. Shielded cables or shielded leads (including power leads and wire grounds) within cables shall be used only if they have been specified in installation drawings. Cables shall be checked against installation requirements to verify proper construction techniques such as use of twisted pairs, shielding, and shield terminations. Details on the cable construction used for testing shall be included in the EMITP.

4.8.5.1 Interconnecting leads and cables. Individual leads shall be grouped into cables in the same manner as in the actual installation. Total interconnecting cable lengths in the setup shall be the same as in the actual platform installation. If a cable is longer than 10 meters, at least 10 meters shall be included. When cable lengths are not specified for the installation, cables shall be sufficiently long to satisfy the conditions specified below. At least 2 meters (except for cables which are shorter in the actual installation) of each interconnecting cable shall be run parallel to the front boundary of the setup. Remaining cable lengths shall be routed to the back of the setup and shall be placed in a zig-zagged arrangement. When the setup includes more than one cable, individual cables shall be separated by 2 centimeters measured from their outer circumference. For bench top setups using ground planes, the cable closest to the front boundary shall be placed 10 centimeters from the front edge of the ground plane. All cables shall be supported 5 centimeters above the ground plane.

4.8.5.2 Input power leads. Two meters of input power leads (including returns) shall be routed parallel to the front edge of the setup in the same manner as the interconnecting leads. The power leads shall be connected to the LISNs (see 4.6). Power leads that are part of an interconnecting cable shall be separated out at the EUT connector and routed to the LISNs. After the 2 meter exposed length, the power leads shall be terminated at the LISNs in as short a distance as possible. The total length of power lead from the EUT electrical connector to the LISNs shall not exceed 2.5 meters. All power leads shall be supported 5 centimeters above the ground plane. If the power

leads are twisted in the actual installation, they shall be twisted up to the LISNs.

4.8.6 Electrical and mechanical interfaces. All electrical input and output interfaces shall be terminated with either the actual equipment from the platform installation or loads which simulate the electrical properties (impedance, grounding, balance, and so forth) present in the actual installation. Signal inputs shall be applied to all applicable electrical interfaces to exercise EUT circuitry. EUTs with mechanical outputs shall be suitably loaded. When variable electrical or mechanical loading is present in the actual installation, testing shall be performed under expected worst case conditions. When active electrical loading (such as a test set) is used, precautions shall be taken to insure the active load meets the ambient requirements of paragraph 4.4 when connected to the setup, and that the active load does not respond to susceptibility signals. Antenna ports on the EUT shall be terminated with shielded, matched loads.

4.9 Operation of EUT. During emission measurements, the EUT shall be placed in an operating mode which produces maximum emissions. During susceptibility testing, the EUT shall be placed in its most susceptible operating mode. For EUTs with several available modes (including software controlled operational modes), a sufficient number of modes shall be tested for emissions and susceptibility such that all circuitry is evaluated.

4.9.1 Operating frequencies for tunable RF equipment. Measurements shall be performed with the EUT tuned to not less than three frequencies within each tuning band, tuning unit, or range of fixed channels, consisting of one mid-band frequency and a frequency within ± 5 percent from each end of each band or range of channels.

4.9.2 Operating frequencies for spread spectrum equipment. Operating frequency requirements for two major types of spread spectrum equipment shall be as follows:

- a. Frequency hopping. Measurements shall be performed with the EUT utilizing a hop set which contains 30% of the total possible frequencies. The hop set shall be divided equally into three segments at the low, mid, and high end of the EUT's operational frequency range.
- b. Direct sequence. Measurements shall be performed with the EUT processing data at the highest possible data transfer rate.

4.9.3 Susceptibility monitoring. The EUT shall be monitored during susceptibility testing for indications of degradation or malfunction. This monitoring is normally accomplished through the use of built-in-test (BIT), visual displays, aural outputs, and other measurements of signal outputs and interfaces. Monitoring of EUT performance through installation of special circuitry in the EUT is permissible; however, these modifications shall not influence test results.

4.10 Use of measurement equipment. Measurement equipment shall be as specified in the individual test methods of this standard. Any frequency selective measurement receiver may be used for performing the testing described in this standard provided that the receiver characteristics (that is, sensitivity, selection of bandwidths, detector functions, dynamic range, and frequency of operation) meet the constraints specified in this standard and are sufficient to demonstrate compliance with the applicable limits of MIL-STD-461. Typical instrumentation characteristics may be found in ANSI C63.2.

4.10.1 Detector. A peak detector shall be used for all frequency domain emission and susceptibility measurements. This device detects the peak value of the modulation envelope in the receiver bandpass. Measurement receivers are calibrated in terms of an equivalent Root Mean Square (RMS) value of a sine wave that produces the same peak value. When other measurement devices such as oscilloscopes, non-selective voltmeters, or broadband field strength sensors are used for susceptibility testing, correction factors shall be applied for test signals to adjust the reading to equivalent RMS values under the peak of the modulation envelope.

4.10.2 Computer-controlled receivers. A description of the operations being directed by software for computer-controlled receivers shall be included in the EMITP required by MIL-STD-461. Verification techniques used to demonstrate proper performance of the software shall also be included.

4.10.3 Emission testing.

4.10.3.1 Bandwidths. The measurement receiver bandwidths listed in Table II shall be used for emission testing. These bandwidths are specified at the 6 dB down points for the overall selectivity curve of the receivers. Video filtering shall not be used to bandwidth limit the receiver response. If a controlled video bandwidth is available on the measurement receiver, it shall be set to its greatest value. Larger bandwidths may be used; however, they may result in higher measured emission

levels. NO BANDWIDTH CORRECTION FACTORS SHALL BE APPLIED TO TEST DATA DUE TO THE USE OF LARGER BANDWIDTHS.

TABLE II. Bandwidth and measurement time.

Frequency Range	6 dB Bandwidth	Dwell Time	Minimum Measurement Time Analog Measurement Receiver
30 Hz - 1 kHz	10 Hz	0.15 sec	0.015 sec/Hz
1 kHz - 10 kHz	100 Hz	0.015 sec	0.15 sec/kHz
10 kHz - 250 kHz	1 kHz	0.015 sec	0.015 sec/kHz
250 kHz - 30 MHz	10 kHz	0.015 sec	1.5 sec/MHz
30 MHz - 1 GHz	100 kHz	0.015 sec	0.15 sec/MHz
Above 1 GHz	1 MHz	0.015 sec	15 sec/GHz

4.10.3.2 Emission identification. All emissions regardless of characteristics shall be measured with the measurement receiver bandwidths specified in Table II and compared against the limits in MIL-STD-461. Identification of emissions with regard to narrowband or broadband categorization is not applicable.

4.10.3.3 Frequency scanning. For emission measurements, the entire frequency range for each applicable test shall be scanned. Minimum measurement time for analog measurement receivers during emission testing shall be as specified in Table II. Synthesized measurement receivers shall step in one-half bandwidth increments or less, and the measurement dwell time shall be as specified in Table II.

4.10.3.4 Emission data presentation. Amplitude versus frequency profiles of emission data shall be automatically and continuously plotted. The applicable limit shall be displayed on the plot. Manually gathered data is not acceptable except for plot verification. The plotted data for emissions measurements shall provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and minimum amplitude resolution of 1 dB. The above resolution requirements shall be maintained in the reported results of the EMITR.

4.10.4 Susceptibility testing.

4.10.4.1 Frequency scanning. For susceptibility measurements, the entire frequency range for each applicable test shall be scanned. For swept frequency susceptibility testing, frequency scan rates and frequency step sizes of signal sources shall not exceed the values listed in Table III. The rates and step sizes are specified in terms of a multiplier of the tuned frequency (f_o) of the signal source. Analog scans refer to signal sources which are continuously tuned. Stepped scans refer to signal sources which are sequentially tuned to discrete frequencies. Stepped scans shall dwell at each tuned frequency for a minimum of 1 second. Scan rates and step sizes shall be decreased when necessary to permit observation of a response.

TABLE III. Susceptibility scanning.

Frequency Range	Analog Scans Maximum Scan Rates	Stepped Scans Maximum Step Size
30 Hz - 1 MHz	0.02 f_o /sec	0.01 f_o
1 MHz - 30 MHz	0.01 f_o /sec	0.005 f_o
30 MHz - 1 GHz	0.005 f_o /sec	0.0025 f_o
1 GHz - 8 GHz	0.002 f_o /sec	0.001 f_o
8 GHz - 40 GHz	0.001 f_o /sec	0.0005 f_o

4.10.4.2 Modulation of susceptibility signals.

Susceptibility test signals above 10 kHz shall be pulse modulated at a 1 kHz rate with a 50% duty cycle unless otherwise specified in an individual test method of this standard.

4.10.4.3 Thresholds of susceptibility. When susceptibility indications are noted in EUT operation, a threshold level shall be determined where the susceptible condition is no longer present. Thresholds of susceptibility shall be determined as follows:

- a. When a susceptibility condition is detected, reduce the interference signal until the EUT recovers.
- b. Reduce the interference signal by an additional 6 dB.
- c. Gradually increase the interference signal until the susceptibility condition reoccurs. The resulting level is the threshold of susceptibility.

d. Record this level, frequency range of occurrence, frequency and level of greatest susceptibility, and other test parameters, as applicable.

4.11 Calibration of measuring equipment and antennas. Test equipment and accessories required for measurement in accordance with this standard shall be calibrated under an approved program in accordance with MIL-STD-45662. In particular, measurement antennas, current probes, field sensors, and other devices used in the measurement loop shall be calibrated at least every 2 years unless otherwise specified by the procuring activity, or when damage is apparent. Antenna factors and current probe transfer impedances shall be determined on an individual basis for each device.

4.11.1 Measurement system test. At the start of each emission test, the complete test system (including measurement receivers, cables, attenuators, couplers, and so forth) shall be verified by injecting a known signal, as stated in the individual test method, while monitoring system output for the proper indication.

4.12 Antenna factors. Factors for electric field test antennas shall be determined in accordance with SAE ARP-958.

5. MEASUREMENT PROCEDURES

This section contains the measurement procedures to be used in determining compliance with the emission and susceptibility requirements of MIL-STD-461. The test procedures are applicable for the entire specified frequency range; however, certain equipment or classes of equipment may not require testing throughout the complete measurement frequency range. These modifications are specified in MIL-STD-461. Table IV is an index of measurement procedures by method number and title.

TABLE IV. Index of measurement procedures.

Requirement	Description
CE101	Conducted Emissions, Power Leads, 30 Hz to 10 kHz
CE102	Conducted Emissions, Power Leads, 10 kHz to 10 MHz
CE106	Conducted Emissions, Antenna Terminal, 10 kHz to 40 GHz
CS101	Conducted Susceptibility, Power Leads, 30 Hz to 50 kHz
CS103	Conducted Susceptibility, Antenna Port, Intermodulation, 15 kHz to 10 GHz
CS104	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals, 30 Hz to 20 GHz
CS105	Conducted Susceptibility, Antenna Port, Cross-Modulation, 30 Hz to 20 GHz
CS109	Conducted Susceptibility, Structure Current, 60 Hz to 100 kHz
CS114	Conducted Susceptibility, Bulk Cable Injection, 10 kHz to 400 MHz
CS115	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation
CS116	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10 kHz to 100 MHz
RE101	Radiated Emissions, Magnetic Field, 30 Hz to 100 kHz
RE102	Radiated Emissions, Electric Field, 10 kHz to 18 GHz
RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs, 10 kHz to 40 GHz
RS101	Radiated Susceptibility, Magnetic Field, 30 Hz to 100 kHz
RS103	Radiated Susceptibility, Electric Field, 10 kHz to 40 GHz
RS105	Radiated Susceptibility, Transient Electromagnetic Field

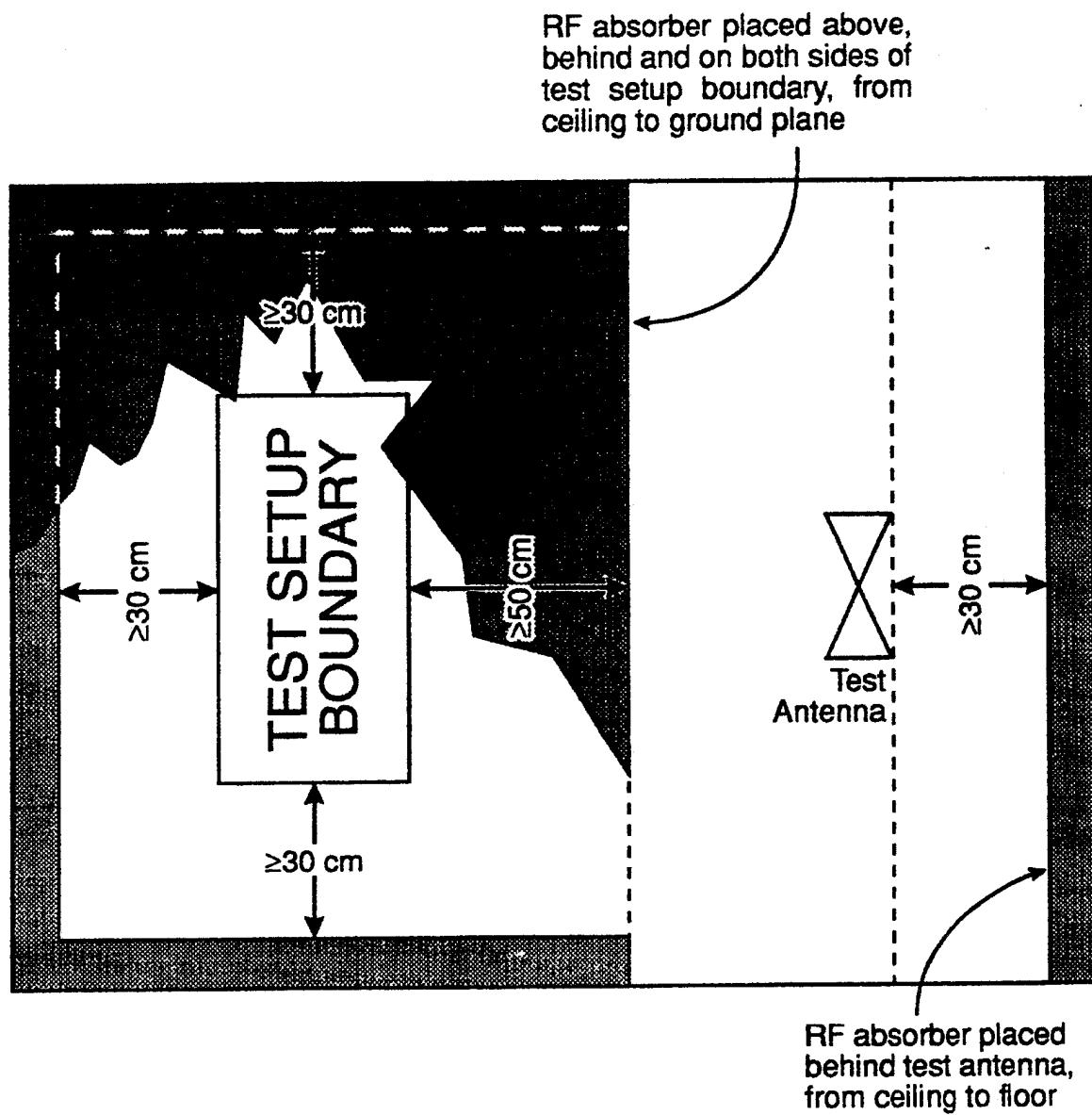


FIGURE 1. RF absorber loading diagram.

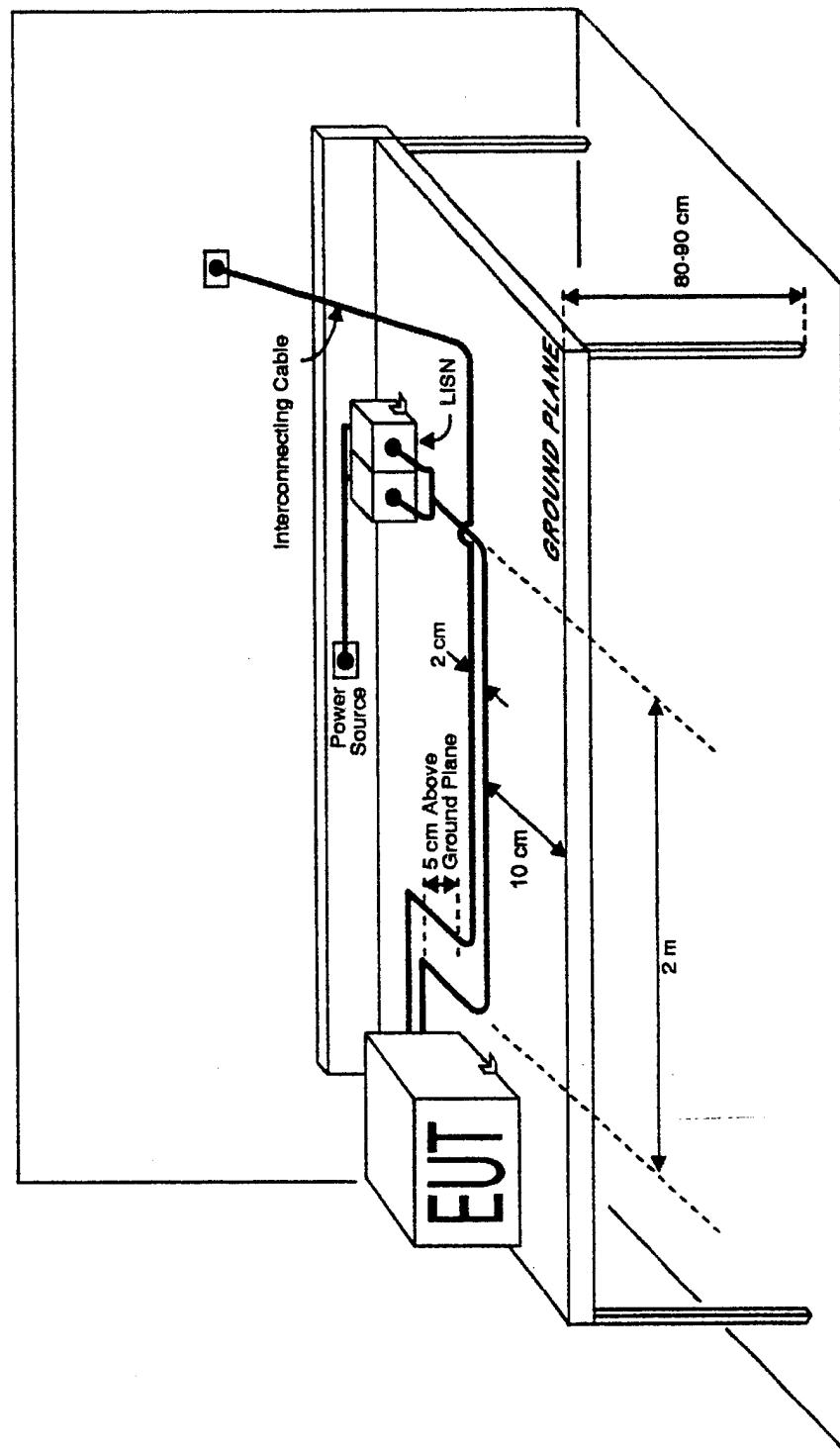


FIGURE 2. General test setup.

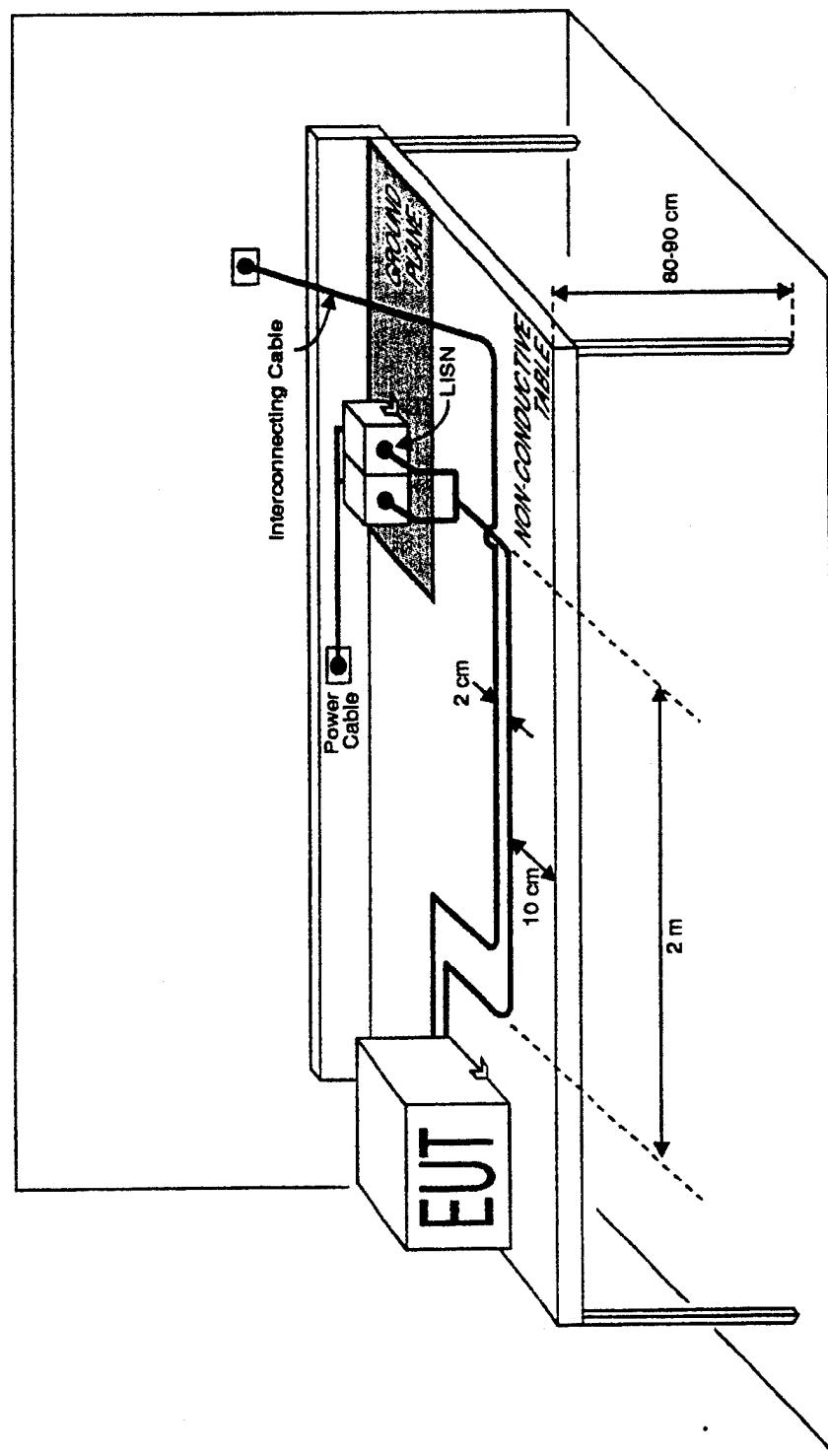


FIGURE 3. Test setup for non-conductive surface mounted EUT.

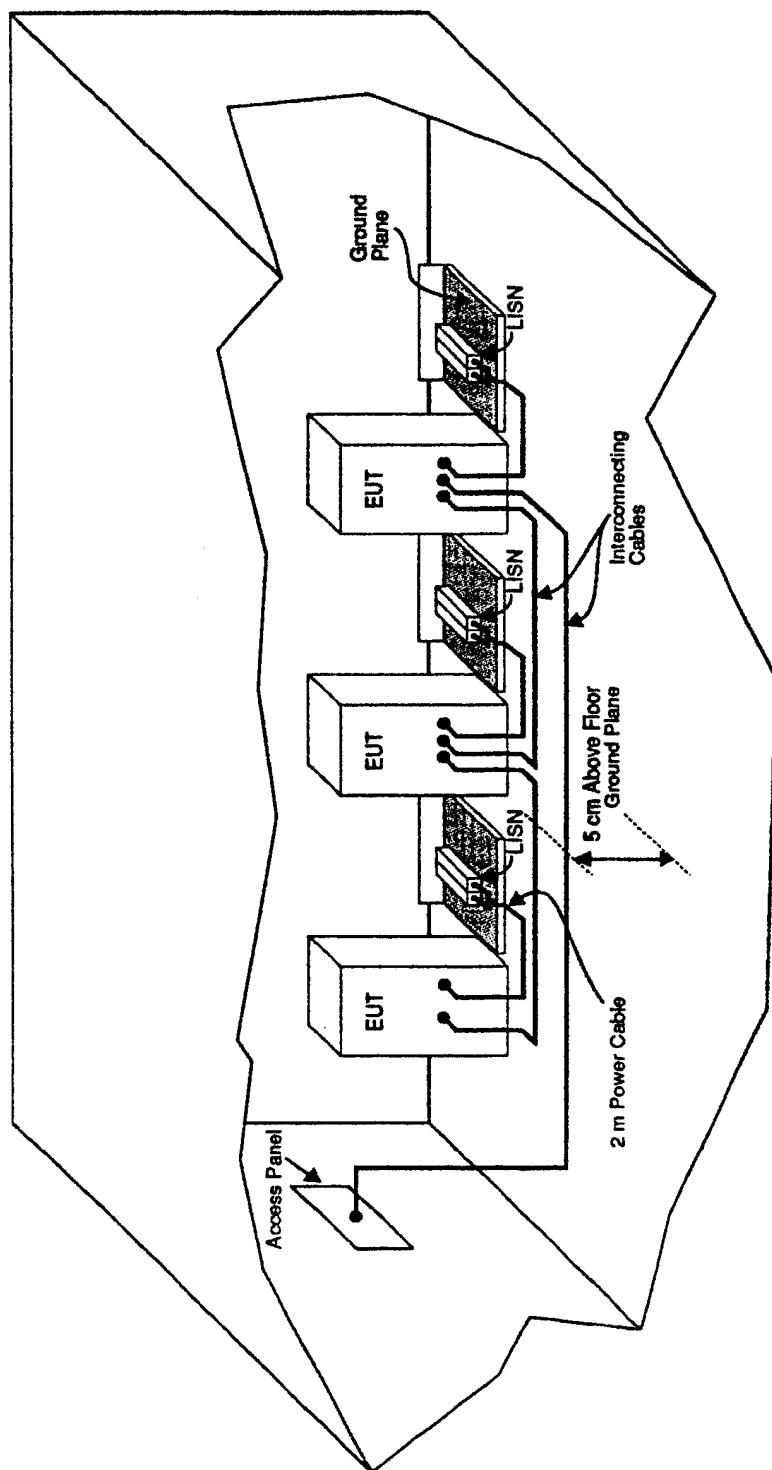


FIGURE 4. Test setup for free standing EUT, multiple EUT,
shielded enclosure.

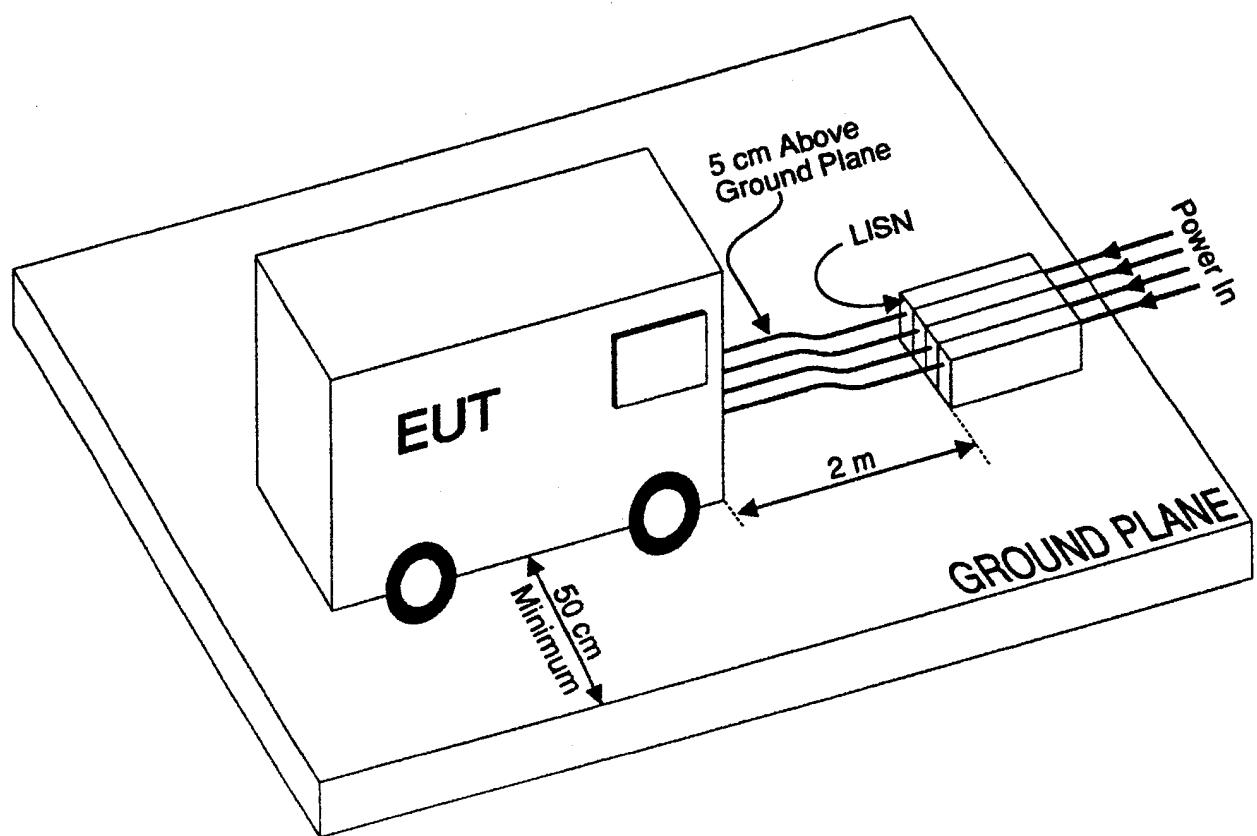


FIGURE 5. Test setup for free standing EUT.

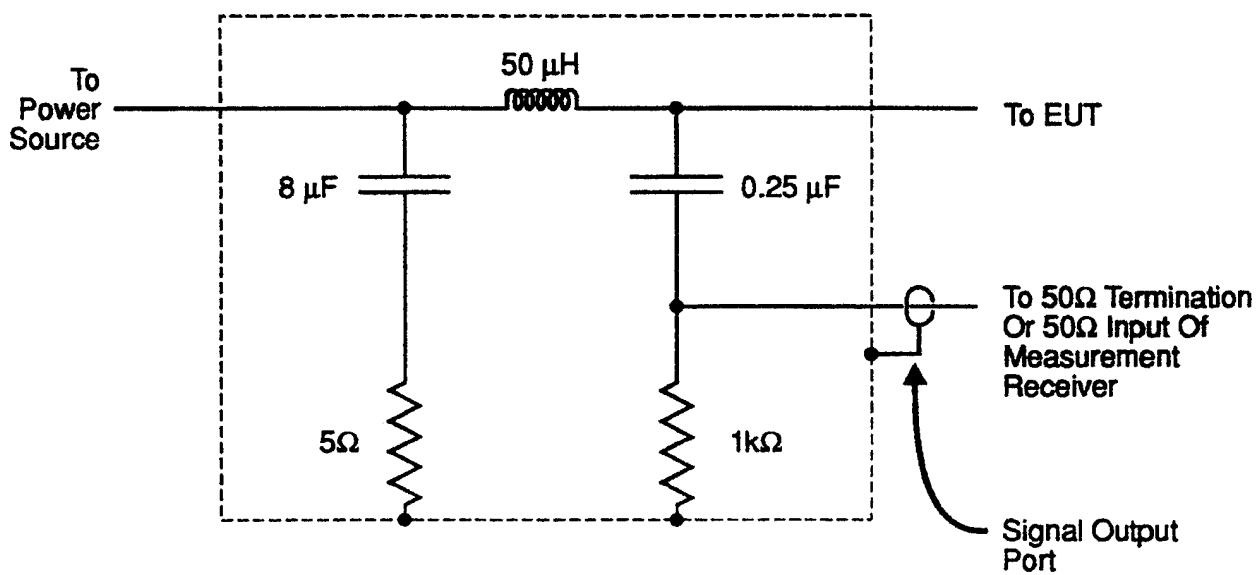


FIGURE 6. LISN schematic.

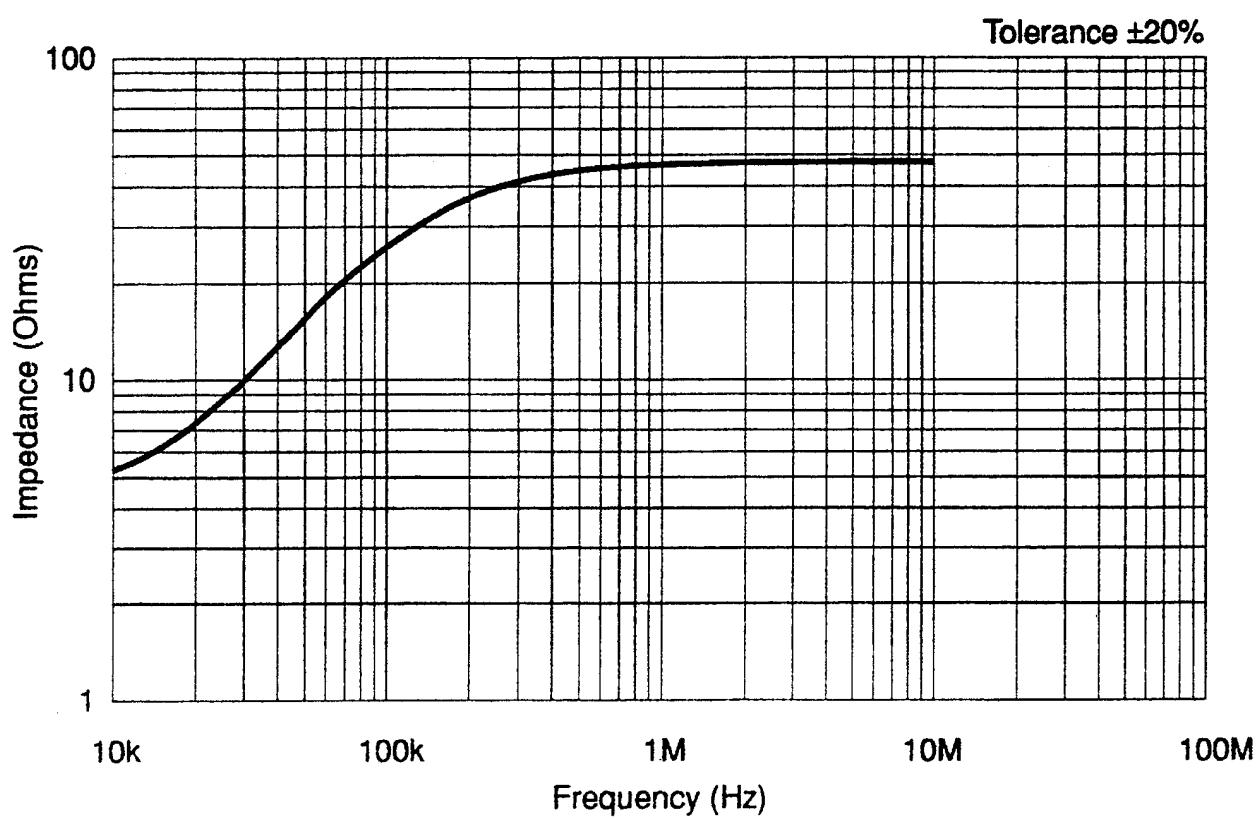


FIGURE 7. LISN impedance.

METHOD CE101

CONDUCTED EMISSIONS, POWER LEADS, 30 Hz TO 10 kHz

1. Purpose. This test method is used to verify that electromagnetic emissions from the EUT do not exceed the specified requirements for power input leads including returns.

2. Test Equipment. The test equipment shall be as follows:

- a. Measurement receivers
- b. Current probes
- c. Signal generator
- d. Data recording device
- e. Oscilloscope
- f. Resistor (R)
- g. LISNs

3. Test Setup. The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and paragraph 4.8 of the general section of this standard. The LISN may be removed or replaced with an alternative stabilization device when approved by the procuring activity.
- b. Calibration. Configure the test setup for the measurement system check as shown in Figure CE101-1.
- c. EUT testing.
 - (1) Configure the test setup for compliance testing of the EUT as shown in Figure CE101-2.
 - (2) Position the current probe 5 cm from the LISN.

4. Test Procedures. The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow a sufficient time for stabilization.

- b. Calibration. Evaluate the overall measurement system from the current probe to the data output device.
 - (1) Apply a calibrated signal level, which is 6 dB below the MIL-STD-461 limit at 1 kHz, 3 kHz, and 10 kHz, to the current probe.
 - (2) Verify the current level, using the oscilloscope and load resistor; also, verify that the current waveform is sinusoidal.
 - (3) Scan the measurement receiver for each frequency in the same manner as a normal data scan. Verify that the data recording device indicates a level within ± 3 dB of the injected level.
 - (4) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
- c. EUT testing. Determine the conducted emissions from the EUT input power leads, including returns.
 - (1) Turn on the EUT and allow sufficient time for stabilization.
 - (2) Select an appropriate lead for testing and clamp the current probe into position.
 - (3) Scan the measurement receiver over the applicable frequency range, using the bandwidths and minimum measurement times specified in the general section of this standard.
 - (4) Repeat 4c(3) for each power lead.

5. Data Presentation. Data presentation shall be as follows:

- a. Continuously and automatically plot amplitude versus frequency profiles on X-Y axis outputs. Manually gathered data is not acceptable except for plot verification.
- b. Display the applicable limit on each plot.
- c. Provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less

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stringent, and a minimum amplitude resolution of 1 dB for each plot.

- d. Provide plots for both the measurement and system check portions of the procedure.

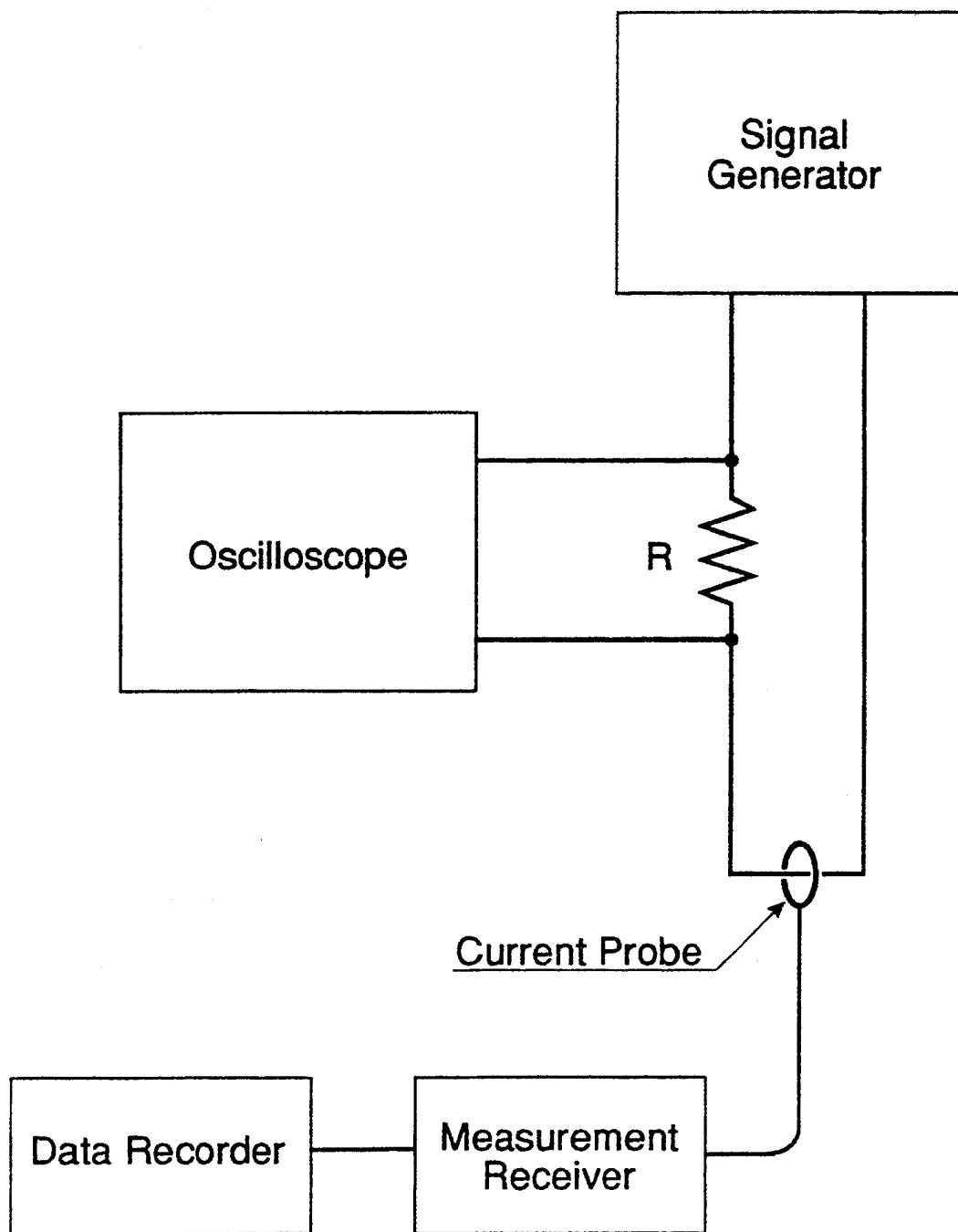


FIGURE CE101-1. Measurement system check setup.

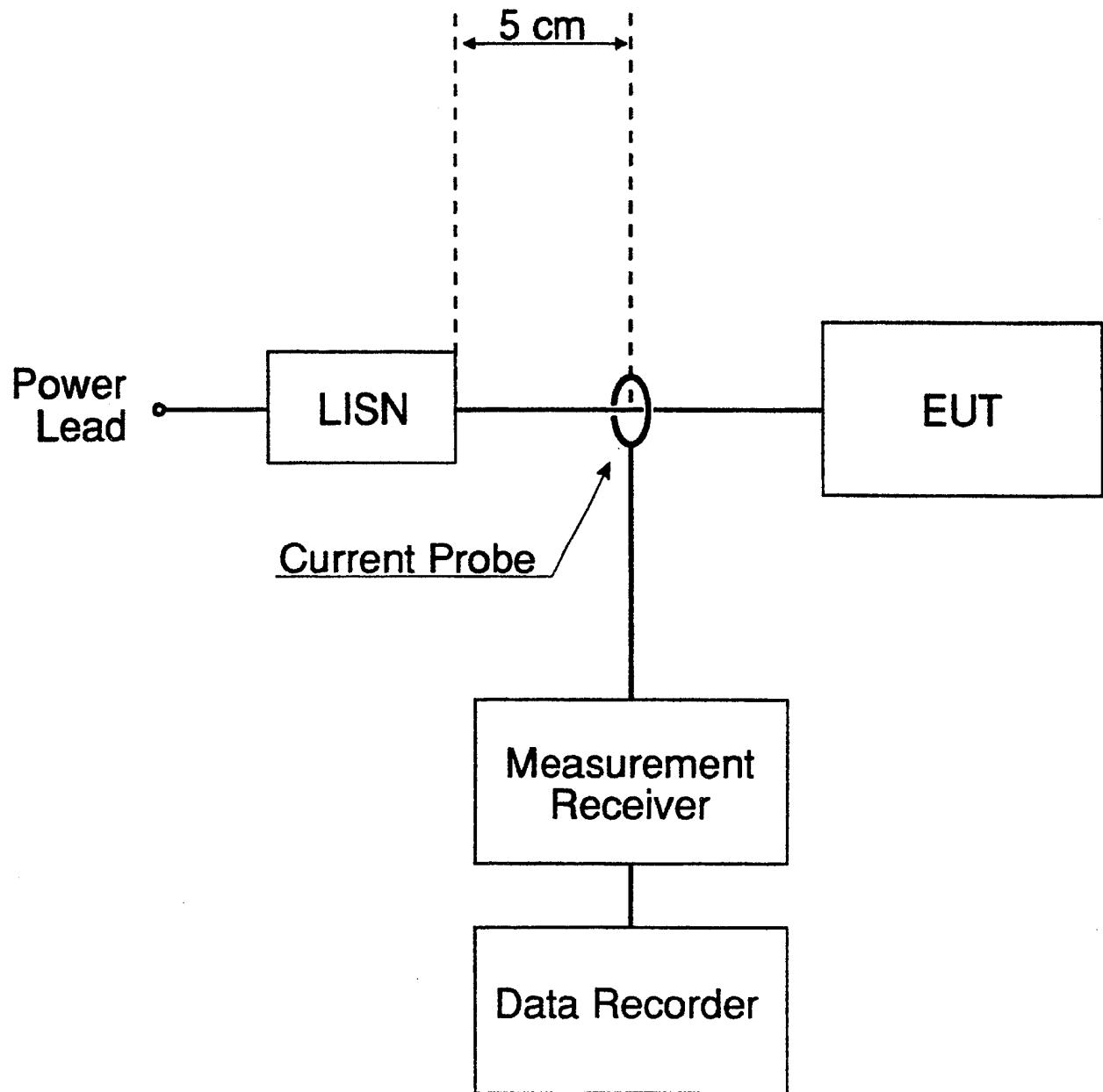


FIGURE CE101-2. Measurement setup.

METHOD CE102

CONDUCTED EMISSIONS, POWER LEADS, 10 kHz TO 10 MHz

1. Purpose. This test method is used to verify that electromagnetic emissions from the EUT do not exceed the specified requirements for power input leads, including returns.

2. Test Equipment. The test equipment shall be as follows:

- a. Measurement receiver
- b. Data recording device
- c. Signal generator
- d. Attenuator, 20 dB
- e. Oscilloscope
- f. LISNs

3. Test Setup. The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and paragraph 4.8 of the general section of this standard.

b. Calibration.

- (1) Configure the test setup for the measurement system check as shown in Figure CE102-1. Ensure that the EUT power source is turned off.
- (2) Connect the measurement receiver to the 20 dB attenuator on the signal output port of the LISN.

c. EUT testing.

- (1) Configure the test setup for compliance testing of the EUT as shown in Figure CE102-2.
- (2) Connect the measurement receiver to the 20 dB attenuator on the signal output port of the LISN.

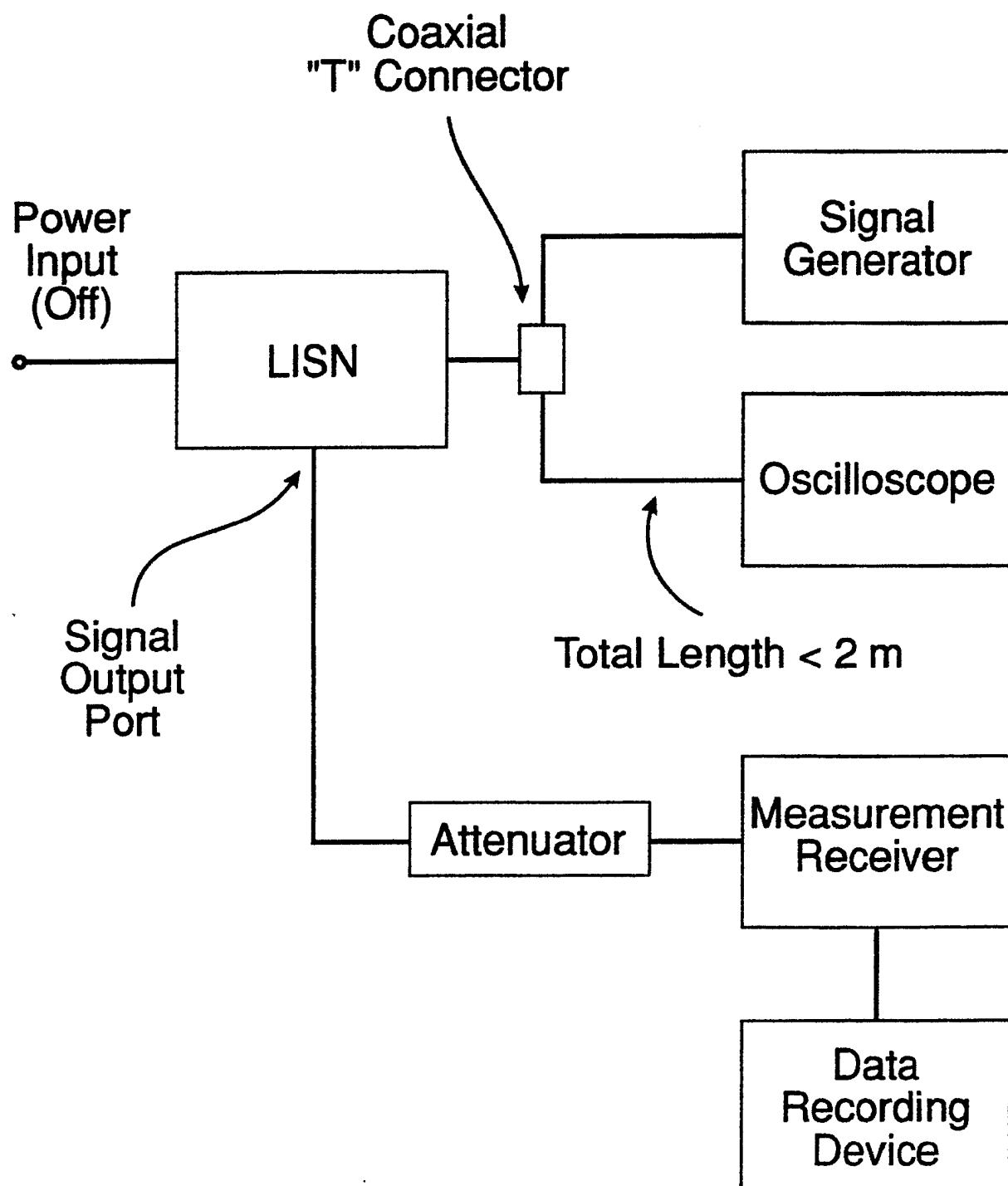
4. Test Procedures. The test procedures shall be as follows:

- a. Calibration. Perform the measurement system check using the measurement system check setup of Figure CE102-1.
 - (1) Turn on the measurement equipment and allow a sufficient time for stabilization.
 - (2) Apply a calibrated signal level, which is 6 dB below the MIL-STD-461 limit at 10 kHz, 100 kHz, 2 MHz and 10 MHz to the power output terminal of the LISN. Also, verify that the voltage waveform is sinusoidal.
 - (3) Scan the measurement receiver for each frequency in the same manner as a normal data scan. Verify that the measurement receiver indicates a level within ± 3 dB of the injected level. Correction factors shall be applied for the 20 dB attenuator and the voltage drop due to the LISN 0.25 microfarad coupling capacitor.
 - (4) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
- b. EUT testing. Perform emission data scans using the measurement setup of Figure CE102-2.
 - (1) Turn on the EUT and allow a sufficient time for stabilization.
 - (2) Select an appropriate lead for testing.
 - (3) Scan the measurement receiver over the applicable frequency range, using the bandwidths and minimum measurement times in the general section of this standard.
 - (4) Repeat 4b(2) and 4b(3) for each power lead.

5. Data Presentation. Data presentation shall be as follows:

- a. Continuously and automatically plot amplitude versus frequency profiles on X-Y axis outputs. Manually gathered data is not acceptable except for plot verification.
- b. Display the applicable limit on each plot.

- c. Provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.
- d. Provide plots for both the measurement system check and measurement portions of the procedure.

FIGURE CE102-1. Measurement system check setup.

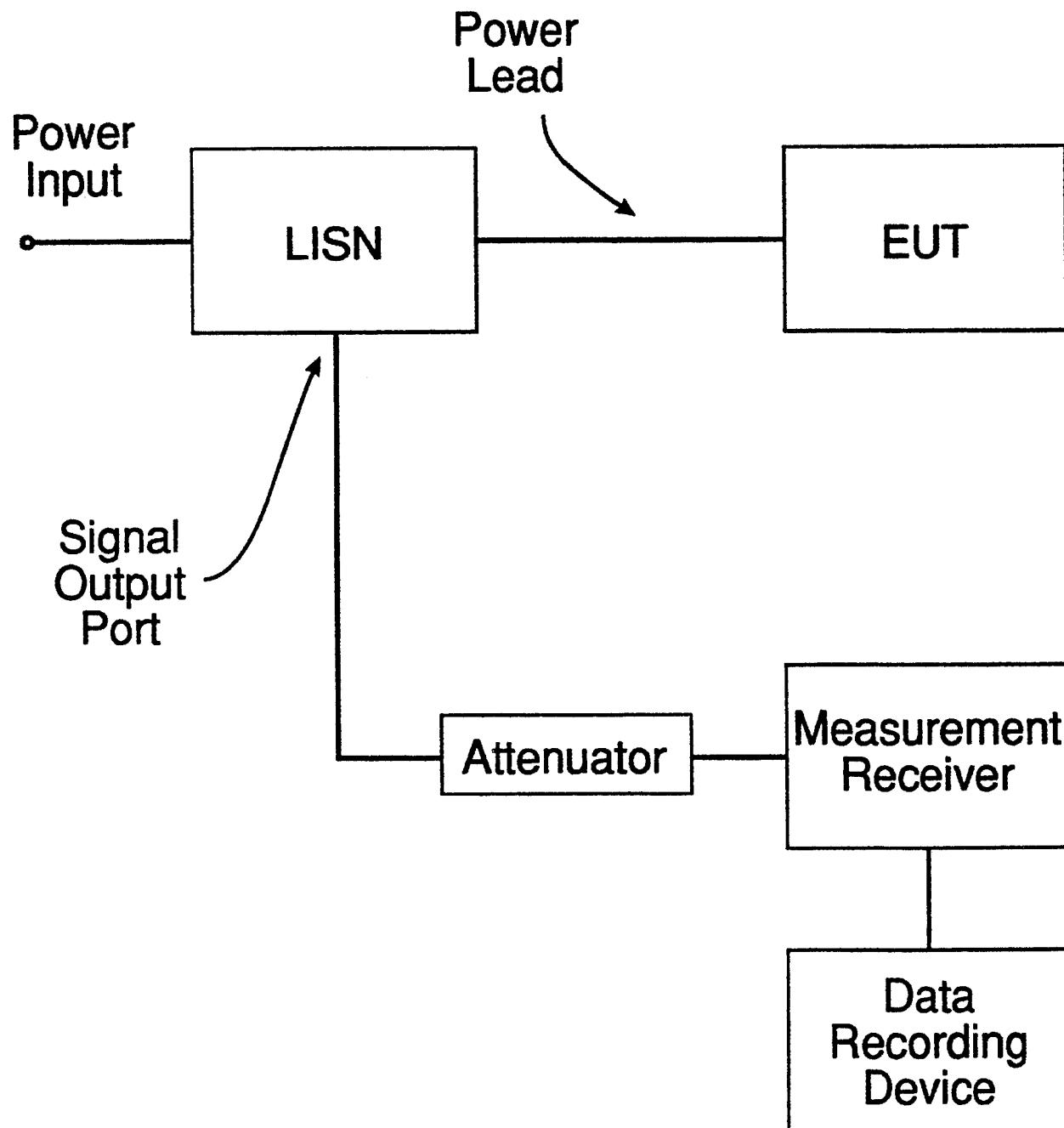


FIGURE CE102-2. Measurement setup.

METHOD CE106

CONDUCTED EMISSIONS, ANTENNA TERMINAL, 10 kHz TO 40 GHz

1. Purpose. This test method is used to verify that conducted emissions appearing at the antenna terminal of the EUT do not exceed specified requirements.

2. Test Equipment. The test equipment shall be as follows:

- a. Measurement receiver
- b. Attenuators
- c. Rejection networks
- d. Directional couplers
- e. Dummy loads
- f. Signal generators
- g. Data recording device

3. Test Setup. It is not necessary to maintain the basic test setup for the EUT as shown and described in figures 2 through 5 and paragraph 4.8 of the general section of this standard. The test setup shall be as follows:

- a. Calibration. Configure the test setup for the signal generator path shown in Figures CE106-1 through CE106-3 as applicable. The choice of figure CE106-1 or CE106-2 is dependent upon the power handling capability of the measuring equipment.
- b. EUT Testing. Configure the test setup for the EUT path shown in Figures CE106-1 through CE106-3 as applicable. The choice of figure CE106-1 or CE106-2 is dependent upon the power handling capability of the measuring equipment.

4. Test Procedures.

4.1 Transmitters (Transmit Mode): The test procedure shall be as follows:

- a. Turn on the measurement equipment and allow a sufficient time for stabilization.

b. Calibration.

- (1) Apply a known calibrated signal level from the signal generator through the system check path at a mid-band fundamental frequency (f_o) in accordance with the general section of this standard.
- (2) Scan the measurement receiver in the same manner as a normal data scan. Verify the measurement receiver detects a level within ± 3 dB of the expected signal.
- (3) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the test.
- (4) Repeat 4.1b(1) through 4.1b(3) at the end points of the frequency range of test.

c. EUT Testing.

- (1) Turn on the EUT and allow sufficient time for stabilization.
- (2) Tune the EUT to the desired test frequency and use the measurement path to complete the rest of this procedure.
- (3) Tune the test equipment to the measurement frequency (f_o) of the EUT and adjust for maximum indication.
- (4) Apply the appropriate modulation for the EUT as indicated in the equipment specification.
- (5) Record the power level of the fundamental frequency (f_o) and the measurement receiver bandwidth.
- (6) Insert the fundamental frequency rejection network, when applicable.
- (7) Scan the frequency range of interest and record the level of all harmonics and spurious emissions. Add all correction factors for cable loss, attenuators and rejection networks. Maintain the same measurement receiver bandwidth used to measure the power level of the fundamental frequency (f_o) in 4.1c(5).

- (8) Verify spurious outputs are from the EUT and not spurious responses of the measurement system.
- (9) Repeat 4.1c(2) through 4.1c(8) for other f_o of the EUT.
- (10) Determine measurement path losses at each spurious frequency as follows:
 - (a) Replace the EUT with a signal generator.
 - (b) Retain all couplers and rejection networks in the measurement path.
 - (c) Determine the losses through the measurement path. The value of attenuators may be reduced to facilitate the end-to-end check with a low level signal generator.

4.2 Transmitters (Stand-by Mode) and Receivers. The test procedure shall be as follows:

- a. Turn on the measurement equipment and allow a sufficient time for stabilization.
- b. Calibration.
 - (1) Apply a calibrated signal level, which 6 dB below the MIL-STD-461 limit, from the signal generator through the system check path at a midpoint test frequency in accordance with the general section of this standard.
 - (2) Scan the measurement receiver in the same manner as a normal data scan. Verify the measurement receiver detects a level within ± 3 dB of the injected signal.
 - (3) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the test.
 - (4) Repeat 4.2b(1) through 4.2b(3) at the end points of the frequency range of test.
- c. EUT Testing.
 - (1) Turn on the EUT and allow sufficient time for stabilization.

- (2) Tune the EUT to the desired test frequency and use the measurement path to complete the rest of this procedure.
- (3) Scan the measurement receiver over the applicable frequency range, using the bandwidths and minimum measurement times of the general section of this standard.
- (4) Repeat 4.2c(2) and 4.2c(3) for other frequencies as required by the general section of this standard.

5. Data Presentation.

5.1 Transmitters (Transmit Mode). The data presentation shall be as follows:

- a. Provide graphical or tabular data showing f_0 and frequencies of all harmonics and spurious emissions measured, power level of the fundamental and all harmonics and spurious emissions, dB down level, and all correction factors including cable loss, attenuator pads, and insertion loss of rejection networks.
- b. The relative dB down level is determined by subtracting the level in 4.1c(7) from that obtained in 4.1c(5).

5.2 Transmitters (Stand-by Mode) and Receivers. The data presentation shall be as follows:

- a. Continuously and automatically plot amplitude versus frequency profiles for each tuned frequency. Manually gathered data is not acceptable except for plot verification.
- b. Display the applicable limit on each plot.
- c. Provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.
- d. Provide plots for both the measurement and system check portions of the procedure.

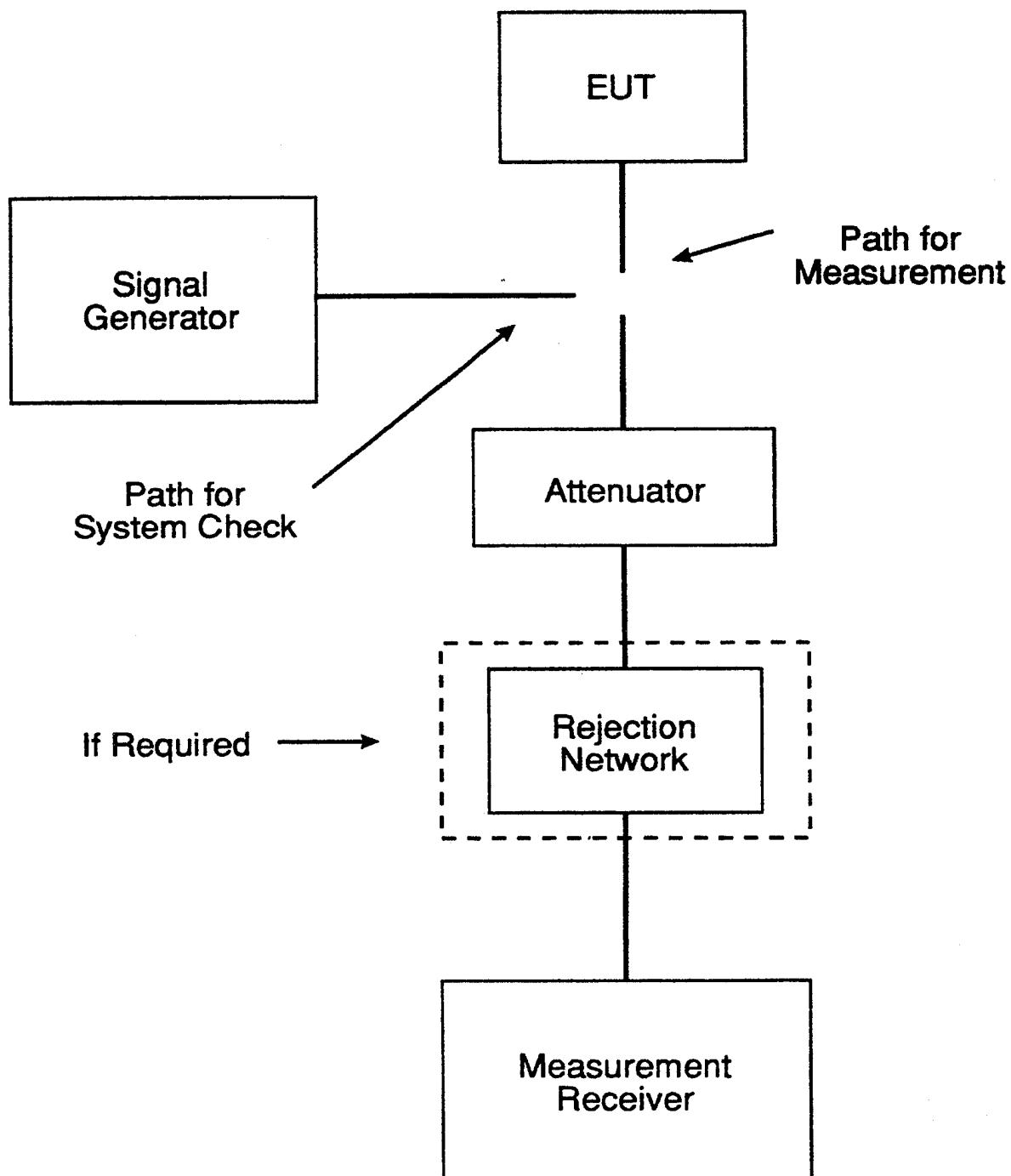
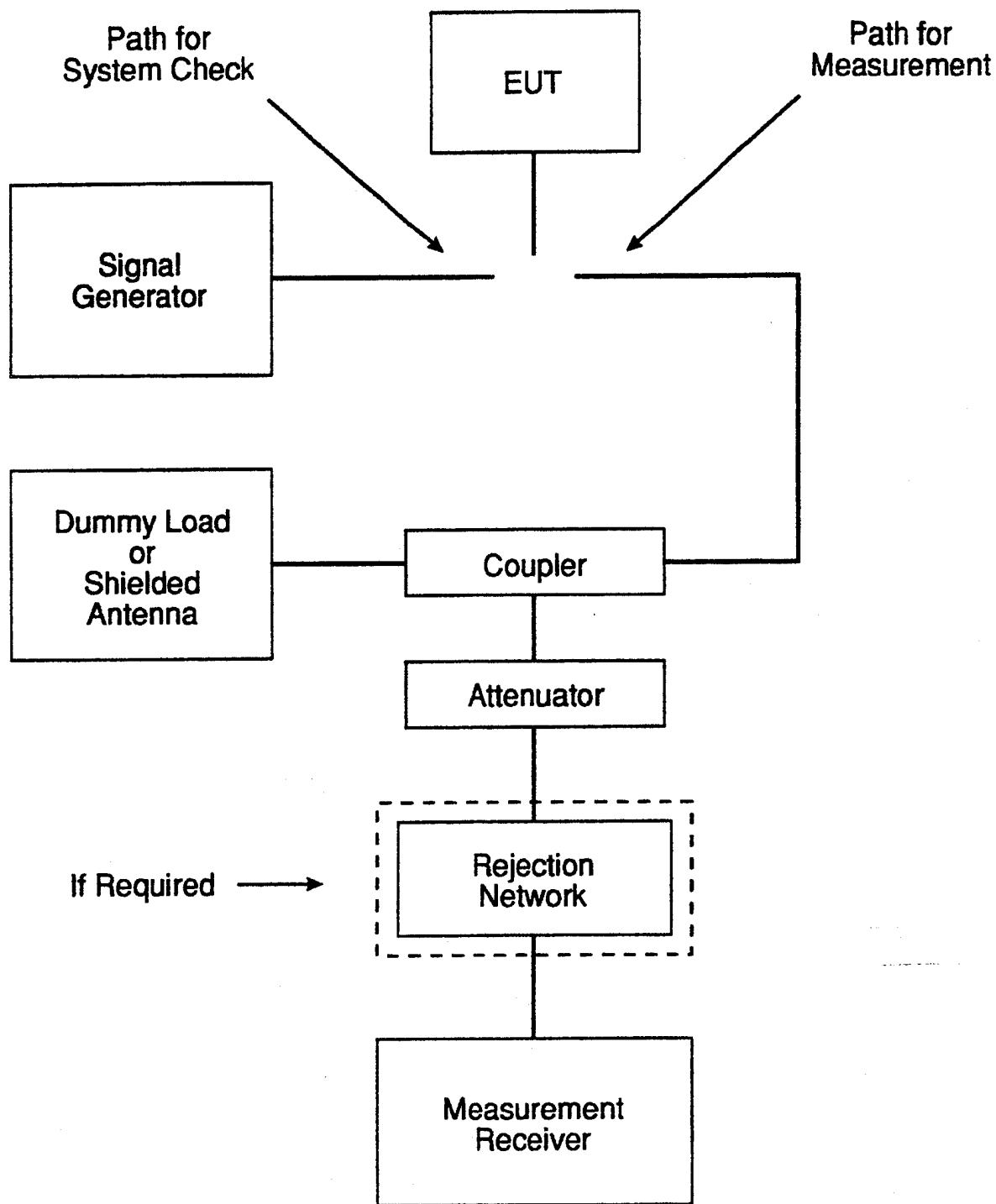


FIGURE CE106-1. Setup for low power transmitter.

FIGURE CE106-2. Setup for high power transmitter.

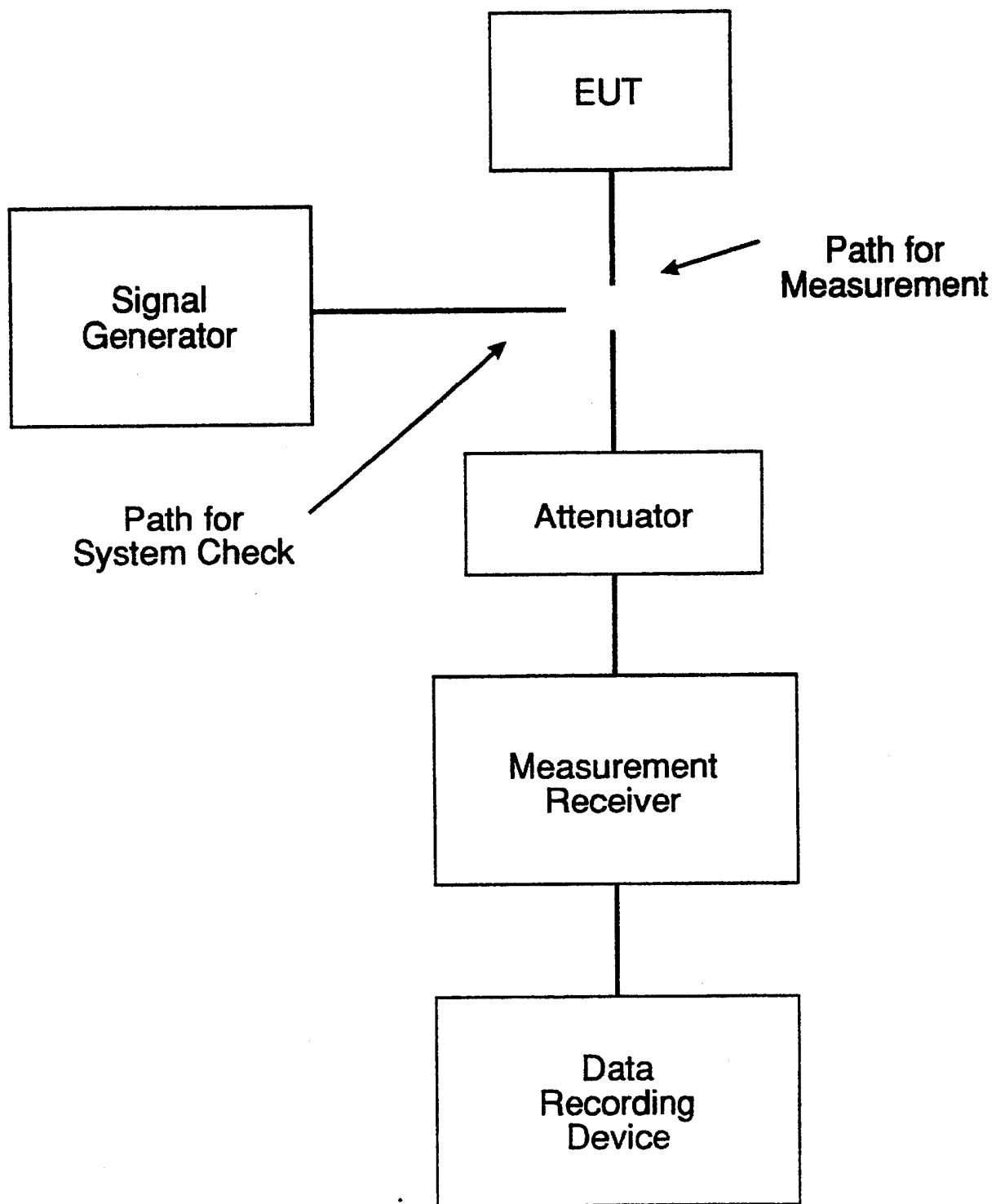


FIGURE CE106-3. Setup for transmitters (stand-by mode) and receivers.

METHOD CS101

CONDUCTED SUSCEPTIBILITY, POWER LEADS, 30 Hz TO 50 kHz

1. Purpose. This test method is used to verify the ability of the EUT to withstand signals coupled onto input power leads.

2. Test Equipment. The test equipment shall be as follows:

- a. Signal generator
- b. Power amplifier
- c. Oscilloscope
- d. Coupling transformer
- e. Capacitor, 10 μ F
- f. Isolation transformer
- g. Resistor, 0.5 ohm
- h. LISNs

3. Test Setup. The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and paragraph 4.8 of the general section of this standard.
- b. Calibration. Configure the test equipment in accordance with Figure CS101-1. Set up the oscilloscope to monitor the voltage across the 0.5 ohm resistor.
- c. EUT testing.
 - (1) For DC or single phase AC power, configure the test equipment as shown in Figure CS101-2.
 - (2) For three phase delta power, configure the test setup as shown in Figure CS101-3.
 - (3) For three phase wye power (four power leads), configure the test setup as shown in Figure CS101-4.

4. Test Procedures. The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow sufficient time for stabilization.
- b. Calibration.
 - (1) Set the signal generator to the lowest test frequency.
 - (2) Increase the applied signal until the oscilloscope indicates the voltage level corresponding to the maximum required power level specified in MIL-STD-461. Verify the output waveform is sinusoidal.
 - (3) Record the setting of the signal source.
 - (4) Scan the required frequency range for testing and record the signal source setting needed to maintain the required power level.
- c. EUT Testing.
 - (1) Turn on the EUT and allow sufficient time for stabilization. CAUTION: Exercise care when performing this test since the "safety ground" of the oscilloscope is disconnected and a shock hazard may be present.
 - (2) Set the signal generator to the lowest test frequency. Increase the signal level until the required voltage or power level is reached on the power lead. (Note: Voltage is limited to the level calibrated in 4b(2).)
 - (3) While maintaining at least the required signal level, scan through the required frequency range at a rate no greater than specified in Table III of the general section of this standard.
 - (4) Susceptibility evaluation.
 - (a) Monitor the EUT for degradation of performance.
 - (b) If susceptibility is noted, determine the level at which the undesirable response is no longer present and verify that it is above the MIL-STD-461 requirement.

- (5) Repeat 4c(2) through 4c(4) for each power lead, as required. For three phase delta power, the measurements shall be made according to the following table:

Coupling Transformer in Line	Voltage Measurement From
A	A to B
B	B to C
C	C to A

For three phase wye power (four leads) the measurements shall be made according to the following table:

Coupling Transformer in Line	Voltage Measurement From
A	A to neutral
B	B to neutral
C	C to neutral

5. Data Presentation. Data presentation shall be as follows:

- a. Provide graphical or tabular data showing the frequencies and amplitudes at which the test was conducted for each lead.
- b. Provide data on any susceptibility thresholds and the associated frequencies which were determined for each power lead.
- c. Provide indications of compliance with the MIL-STD-461 requirements for the susceptibility evaluation specified in 4c for each lead.

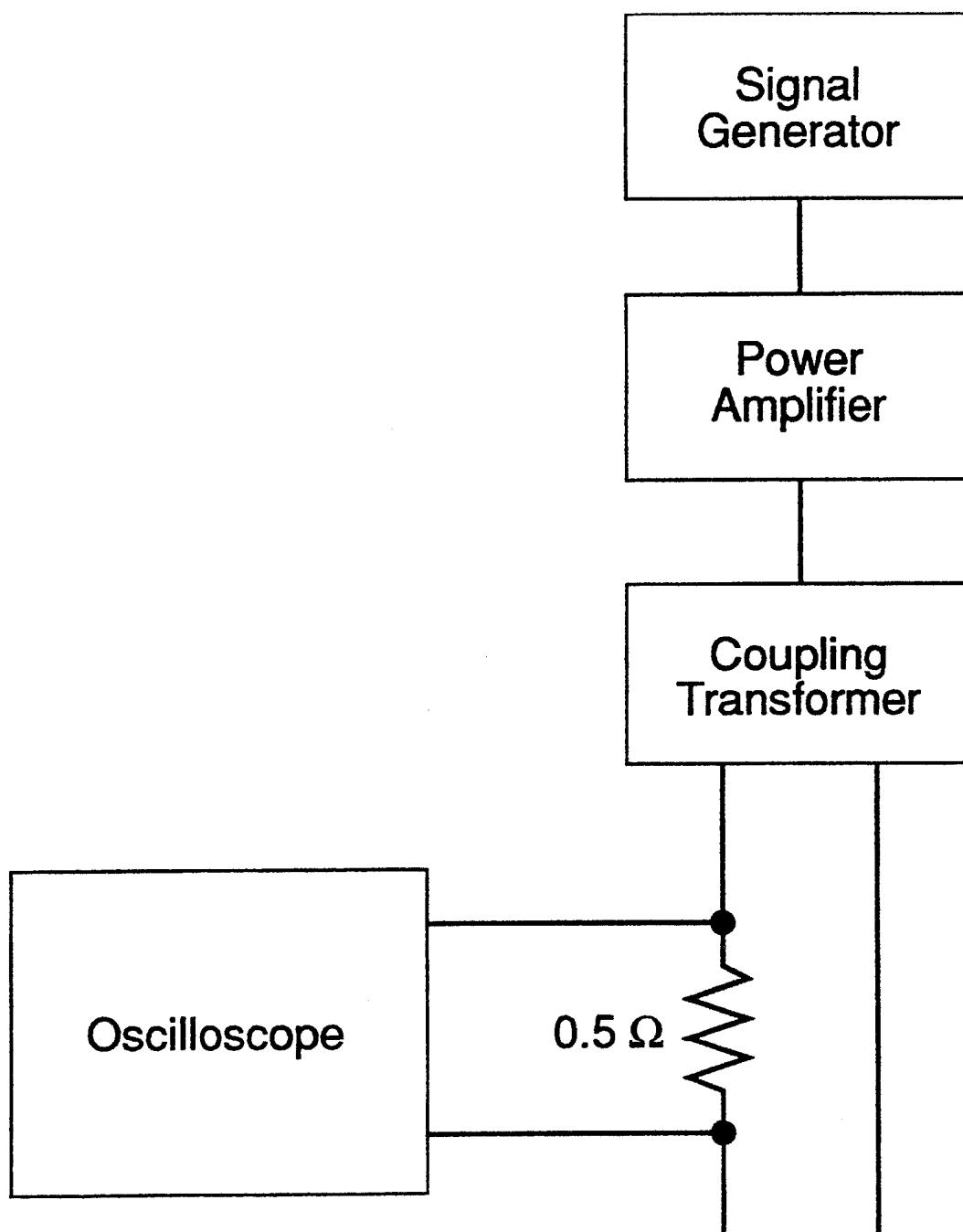


FIGURE CS101-1. Calibration.

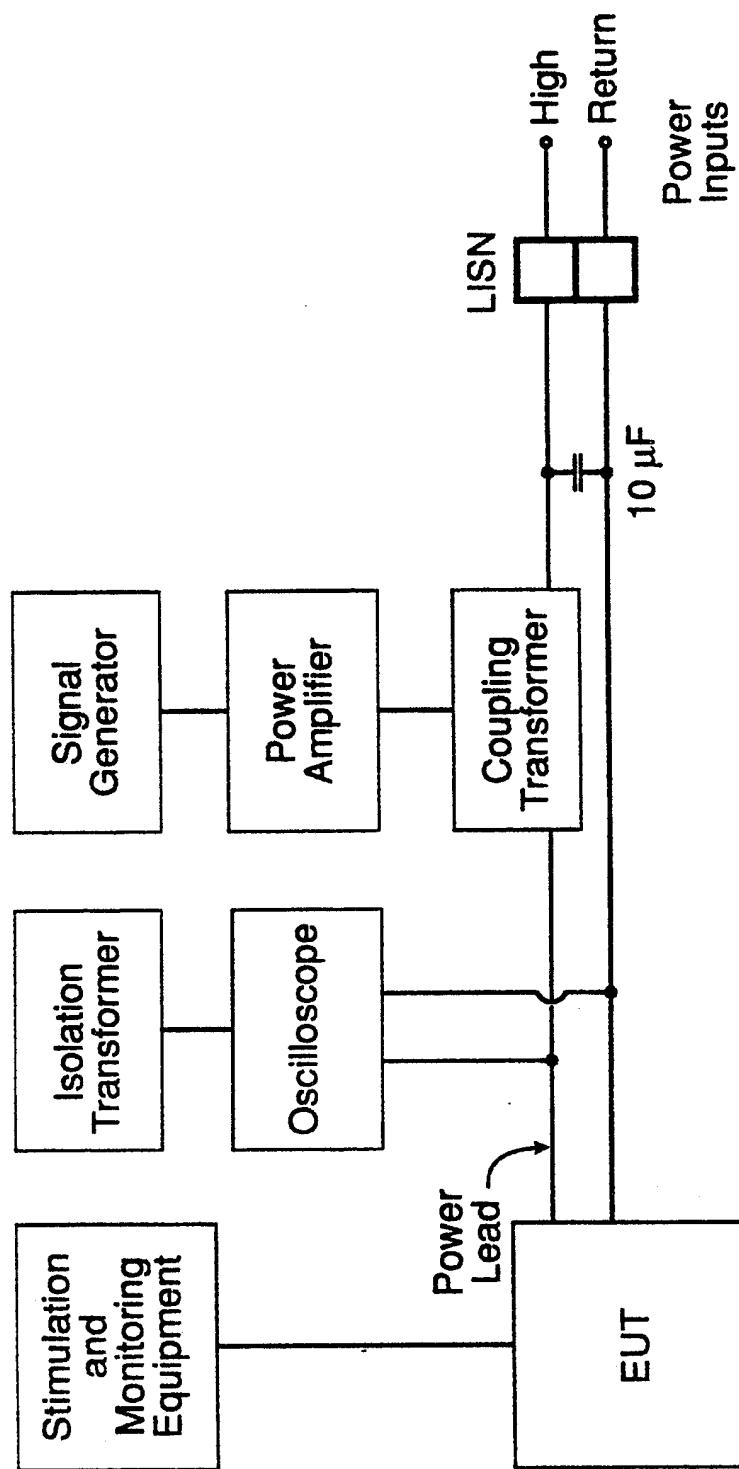
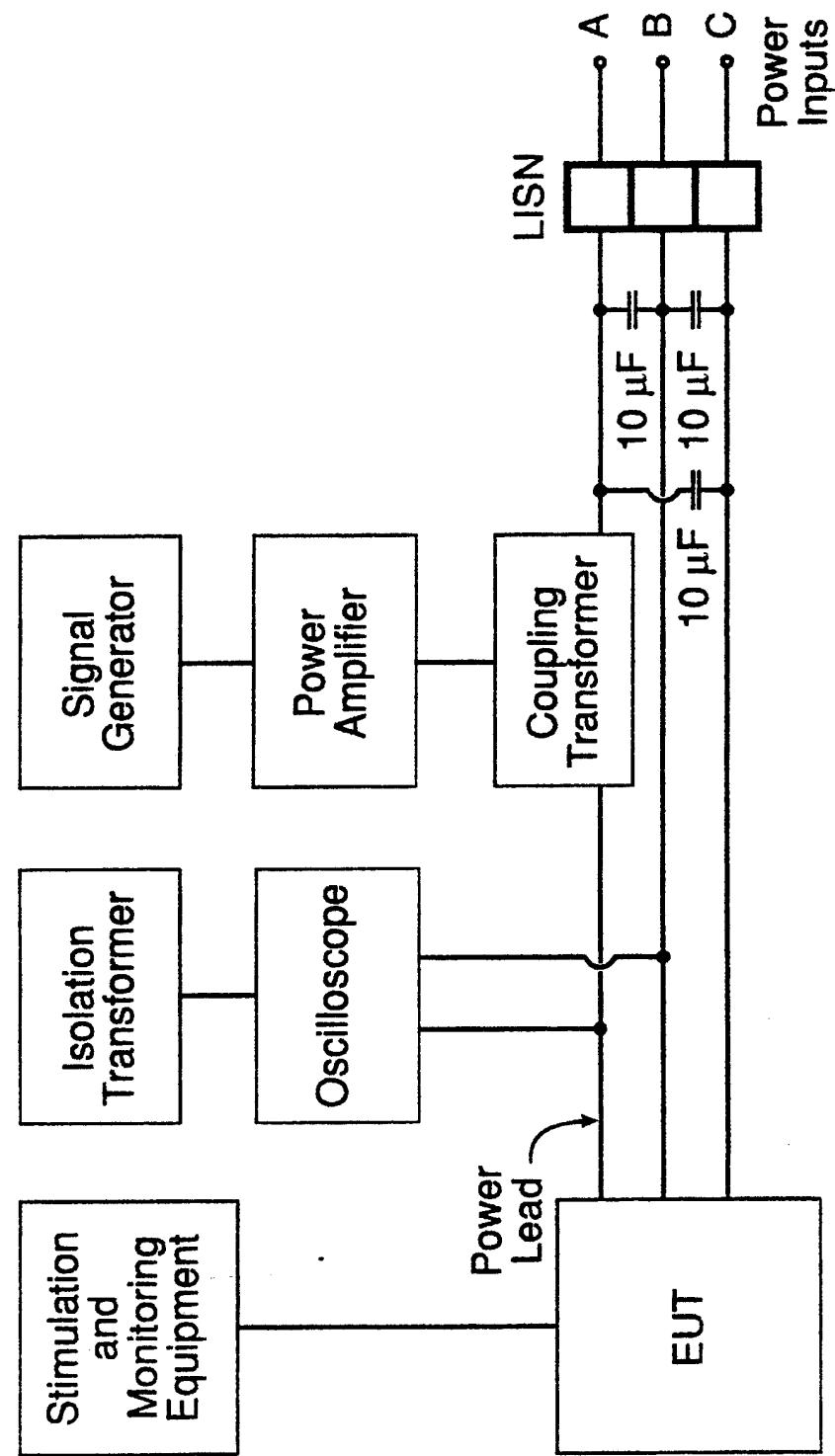
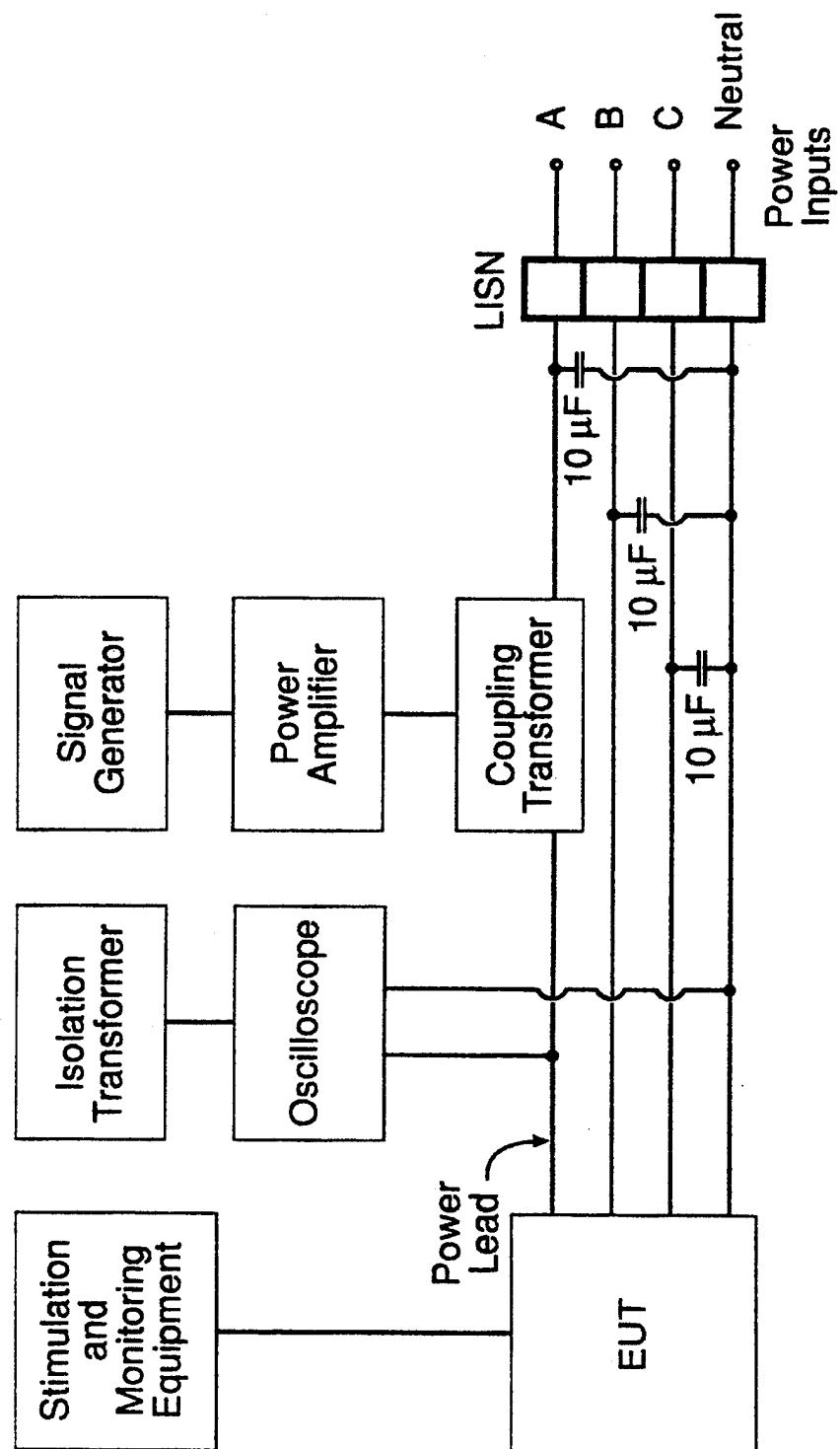


FIGURE CS101-2. Signal injection, DC or single phase AC.

FIGURE CS101-3. Signal injection, 3-phase delta.

FIGURE CS101-4. Signal injection, 3-phase wye.

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METHOD CS103

CONDUCTED SUSCEPTIBILITY, ANTENNA PORT, INTERMODULATION,
15 kHz TO 10 GHz

1. Purpose. This test method is to determine the presence of intermodulation products that may be caused by undesired signals at the EUT antenna input terminals.
2. Test Requirements. The required test equipment, test setup, test procedures, and data presentation shall be determined in accordance with the guidance provided in the appendix of this standard. The test requirements shall be described in the EMITP required by MIL-STD-461.

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METHOD CS104

CONDUCTED SUSCEPTIBILITY, ANTENNA PORT, REJECTION OF
UNDESIRED SIGNALS, 30 Hz TO 20 GHz

1. Purpose. This test method is to determine the presence of spurious responses that may be caused by undesired signals at the EUT antenna input terminals.

2. Test Requirements. The required test equipment, test setup, test procedures, and data presentation shall be determined in accordance with the guidance provided in the appendix of this standard. The test requirements shall be described in the EMITP required by MIL-STD-461.

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METHOD CS105

CONDUCTED SUSCEPTIBILITY, ANTENNA PORT, CROSS-MODULATION,
30 Hz TO 20 GHz

1. Purpose. This test method is to determine the presence of cross-modulation products that may be caused by undesired signals at the EUT antenna terminals.
2. Test Requirements. The required test equipment, test setup, test procedures, and data presentation shall be determined in accordance with the guidance provided in the appendix of this standard. The test requirements shall be described in the EMITP required by MIL-STD-461.

METHOD CS109

CONDUCTED SUSCEPTIBILITY, STRUCTURE CURRENT, 60 Hz TO 100 kHz

1. Purpose. This test method is used to verify the ability of the EUT to withstand structure currents.

2. Test Equipment. The test equipment shall be as follows:

- a. Signal generator
- b. Oscilloscope or voltmeter
- c. Resistor, 0.5 ohm
- d. Isolation transformers

3. Test Setup. The test setup shall be as follows:

- a. It is not necessary to maintain the basic test setup for the EUT as shown and described in figures 2 through 5 and paragraph 4.8 of the general section of this standard.
- b. Calibration. No special calibration is required.
- c. EUT testing. CAUTION: Exercise care when setting up and performing this test since the input power safety ground leads are disconnected.
 - (1) As shown in Figure CS109-1, configure the EUT and the test equipment (including the test signal source, the test current measurement equipment, and the equipment required for operating the EUT or measuring performance degradation) to establish a single-point ground for the test setup.
 - (a) Using isolation transformers, isolate all AC power sources. For DC power, isolation transformers are not applicable.
 - (b) Disconnect the safety ground leads of all input power cables.
 - (c) Place the EUT and the test equipment on non-conductive surfaces.

(2) The test points for injected currents shall be at diagonal extremes across all surfaces of the EUT.

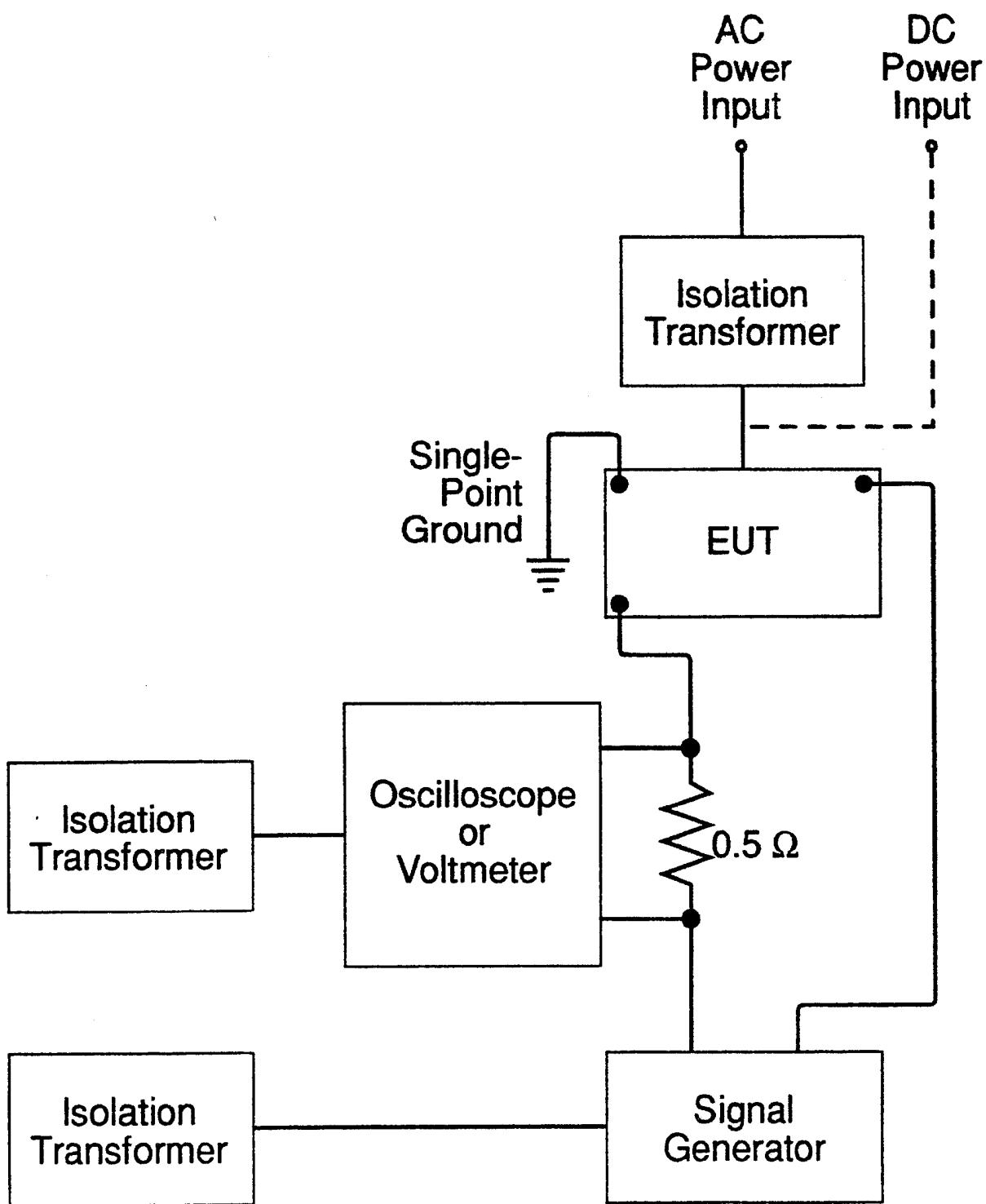
(3) Connect the signal generator and resistor to a selected set of test points.

4. Test Procedures. The test procedures shall be as follows:

- a. Turn on the EUT and measurement equipment and allow sufficient time for stabilization.
- b. Set the signal generator to the lowest required frequency. Adjust the signal generator to the required level. Monitor the current by measuring the voltage developed across the resistor.
- c. Scan the signal generator over the required frequency range in accordance with the general section of this standard while maintaining the current level as specified in the applicable limit. Monitor the EUT for susceptibility.
- d. If susceptibility is noted, determine the level at which the undesirable response is no longer present and verify that it is above the MIL-STD-461 requirement.
- e. Repeat 4b through 4d for each diagonal set of test points on each surface of the EUT to be tested.

5. Data Presentation. Data presentation shall be as follows:

- a. Provide a table showing the mode of operation, susceptible frequency, current threshold level, current limit level, and susceptible test points.

FIGURE CS109-1. Test Configuration.

METHOD CS114

CONDUCTED SUSCEPTIBILITY, BULK CABLE INJECTION, 10 kHz TO 400 MHz

1. Purpose. This test method is used to verify the ability of the EUT to withstand RF signals coupled onto EUT associated cabling.
2. Test Equipment. The test equipment shall be as follows:
 - a. Measurement receivers
 - b. Current injection probes
 - c. Current probes
 - d. Calibration fixture: coaxial transmission line with 50 ohm characteristic impedance, coaxial connections on both ends, and space for an injection probe around the center conductor.
 - e. Directional couplers
 - f. Signal generators
 - g. Plotter
 - h. Attenuators, 50 ohm
 - i. Coaxial loads, 50 ohm
 - j. Power amplifiers
 - k. LISNs
3. Test Setup. The test setup shall be as follows:
 - a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and paragraph 4.8 of the general section of this standard.
 - b. Calibration. Configure the test equipment in accordance with Figure CS114-1 for calibrating injection probes.
 - (1) Place the injection probe around the center conductor of the calibration fixture.

- (2) Terminate one end of the calibration fixture with a 50 ohm load and terminate the other end with an attenuator connected to measurement receiver A.
 - c. EUT Testing. Configure the test equipment as shown in Figure CS114-2 for testing of the EUT.
 - (1) Place the injection and monitor probes around a cable bundle interfacing with an EUT connector.
 - (2) Locate the monitor probe 5 cm from the connector. If the overall length of the connector and backshell exceeds 5 cm, position the monitor probe as close to the connector's backshell as possible.
 - (3) Position the injection probe 5 cm from the monitor probe.
4. Test Procedures. The test procedures shall be as follows:
- a. Turn on the measurement equipment and allow sufficient time for stabilization.
 - b. Calibration. Perform the following procedures using the calibration setup.
 - (1) Set the signal generator to 10 kHz, unmodulated.
 - (2) Increase the applied signal until measurement receiver A indicates the current level specified in MIL-STD-461 is flowing in the center conductor of the calibration fixture.
 - (3) Record the "forward power" to the injection probe indicated on measurement receiver B.
 - (4) Scan the frequency band from 10 kHz to 400 MHz and record the forward power needed to maintain the required current amplitude.
 - c. EUT Testing. Perform the following procedures on each cable bundle interfacing with each electrical connector on the EUT including complete power cables (high sides and returns). Also perform the procedures on power cables with the power returns excluded from the cable bundle.

- (1) Turn on the EUT and allow sufficient time for stabilization.
- (2) Loop circuit impedance characterization.
 - (a) Set the signal generator to 10 kHz, unmodulated.
 - (b) Apply a power level of approximately 1 mW to the injection probe and record both the power level indicated by measurement receiver B and the induced current level indicated by measurement receiver A.
 - (c) Scan the frequency range from 10 kHz to 400 MHz and record the applied power level and induced current level.
 - (d) Normalize the measurement results to amperes for 1 watt of applied power.
- (3) Susceptibility evaluation.
 - (a) Set the signal generator to 10 kHz with 1 kHz pulse wave modulation, 50% duty cycle.
 - (b) Apply the forward power level determined under 4b(4) to the injection probe while monitoring the induced current.
 - (c) Scan the required frequency range in accordance with the general section of this standard while maintaining the forward power level at the calibration level determined under 4b(4), or the maximum current level in MIL-STD-461, whichever is less stringent.
 - (d) Monitor the EUT for degradation of performance during testing.
 - (e) Whenever susceptibility is noted, determine the level at which the undesirable response is no longer present and verify that it is above the MIL-STD-461 requirement.
 - (f) For EUTs with redundant cabling for safety critical reasons such as multiple data buses, use simultaneous multi-cable injection techniques.

5. Data Presentation. Data presentation shall be as follows:

- a. Provide amplitude versus frequency plots for the forward power levels required to obtain the calibration level as determined in 4b.
- b. Provide amplitude versus frequency plots for the amperes for 1 watt of applied power for each EUT connector interface as determined in 4c(2).
- c. Provide tables showing scanned frequency ranges and statements of compliance with the MIL-STD-461 requirement for the susceptibility evaluation of 4c(3) for each interface connector. Provide any susceptibility thresholds which were determined, along with their associated frequencies.

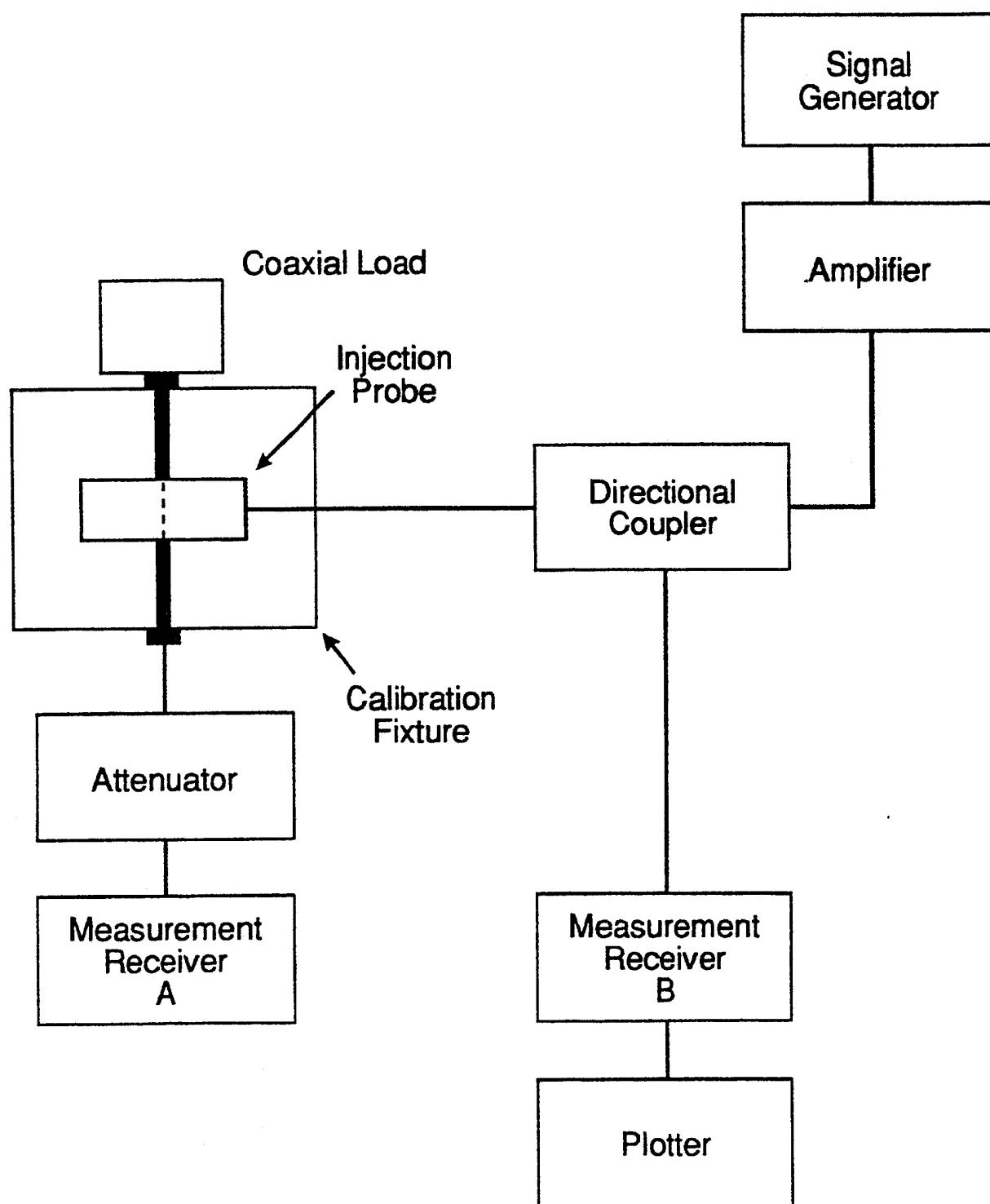


FIGURE CS114-1. Calibration setup.

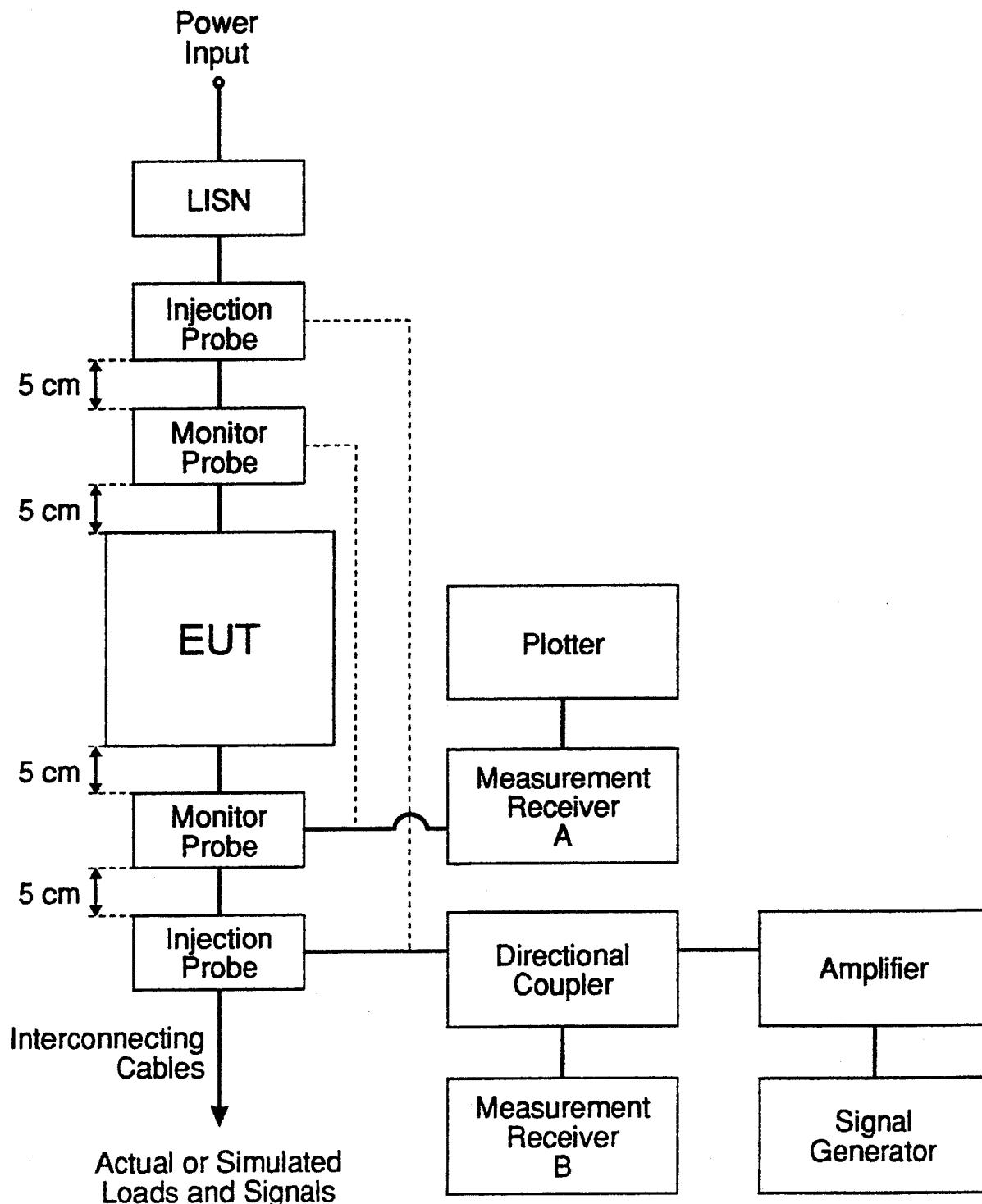


FIGURE CS114-2. Bulk cable injection and loop circuit impedance evaluations.

METHOD CS115

CONDUCTED SUSCEPTIBILITY, BULK CABLE INJECTION,
IMPULSE EXCITATION

1. Purpose. This test method is used to verify the ability of the EUT to withstand impulse signals coupled onto EUT associated cabling.
2. Test Equipment. The test equipment shall be as follows:
 - a. Pulse generator, 50 ohm, charged line
 - b. Current injection probe
 - c. Drive cable, 50 ohm, 2 meters, 0.5 dB or less insertion loss at 500 MHz
 - d. Current probe
 - e. Calibration fixture: coaxial transmission line with 50 ohm characteristic impedance, coaxial connections on both ends, and space for an injection probe around the center conductor.
 - f. Oscilloscope, 50 ohm input impedance
 - g. Attenuators, 50 ohm
 - h. Coaxial loads, 50 ohm
 - i. LISNs
3. Test Setup. The test setup shall be as follows:
 - a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and paragraph 4.8 of the general section of this standard.
 - b. Calibration. Configure the test equipment in accordance with Figure CS115-1 for calibrating the injection probe.
 - (1) Place the injection probe around the center conductor of the calibration fixture.
 - (2) Terminate one end of the calibration fixture with a coaxial load and terminate the other end with an

attenuator connected to an oscilloscope with 50 ohm input impedance.

- c. EUT Testing. Configure the test equipment as shown in Figure CS115-2 for testing of the EUT.
 - (1) Place the injection and monitor probes around a cable bundle interfacing with an EUT connector.
 - (2) Locate the monitor probe 5 cm from the connector. If the overall length of the connector and backshell exceeds 5 cm, position the monitor probe as close to the connector's backshell as possible.
 - (3) Position the injection probe 5 cm from the monitor probe.

4. Test Procedures. The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow sufficient time for stabilization.
- b. Calibration. Perform the following procedures using the calibration setup.
 - (1) Adjust the pulse generator source for the risetime, pulse width, and pulse repetition rate requirements specified in MIL-STD-461.
 - (2) Increase the signal applied to the calibration fixture until the oscilloscope indicates that the current level specified in MIL-STD-461 is flowing in the center conductor of the calibration fixture.
 - (3) Verify that the rise time, fall time, and pulse width portions of the waveform have the correct durations and that the correct repetition rate is present. The precise pulse shape will not be reproduced due to the inductive coupling mechanism.
 - (4) Record the pulse generator amplitude setting.
- c. EUT Testing.
 - (1) Turn on the EUT and allow sufficient time for stabilization.
 - (2) Susceptibility evaluation.

- (a) Adjust the pulse generator, as a minimum, for the amplitude setting determined in 4b(4).
- (b) Apply the test signal at the pulse repetition rate and for the duration specified in MIL-STD-461.
- (c) Monitor the EUT for degradation of performance during testing.
- (d) Whenever susceptibility is noted, determine the level at which the undesirable response is no longer present and verify that it is above the MIL-STD-461 requirement.
- (e) Record the peak current induced in the cable as indicated on the oscilloscope.
- (f) Repeat 4c(2)(a) through 4c(2)(e) on each cable bundle interfacing with each electrical connector on the EUT. For power cables, perform 4c(2)(a) through 4c(2)(e) on complete power cables (high sides and returns) and on the power cables with the power returns excluded from the cable bundle.

5. Data Presentation. Data presentation shall be as follows:

- a. Provide tables showing statements of compliance with the MIL-STD-461 requirement for the susceptibility evaluation of 4c(2) and the induced current level for each interface connector.
- b. Provide any susceptibility thresholds which were determined.
- c. Provide oscilloscope photographs of injected waveforms with test data.

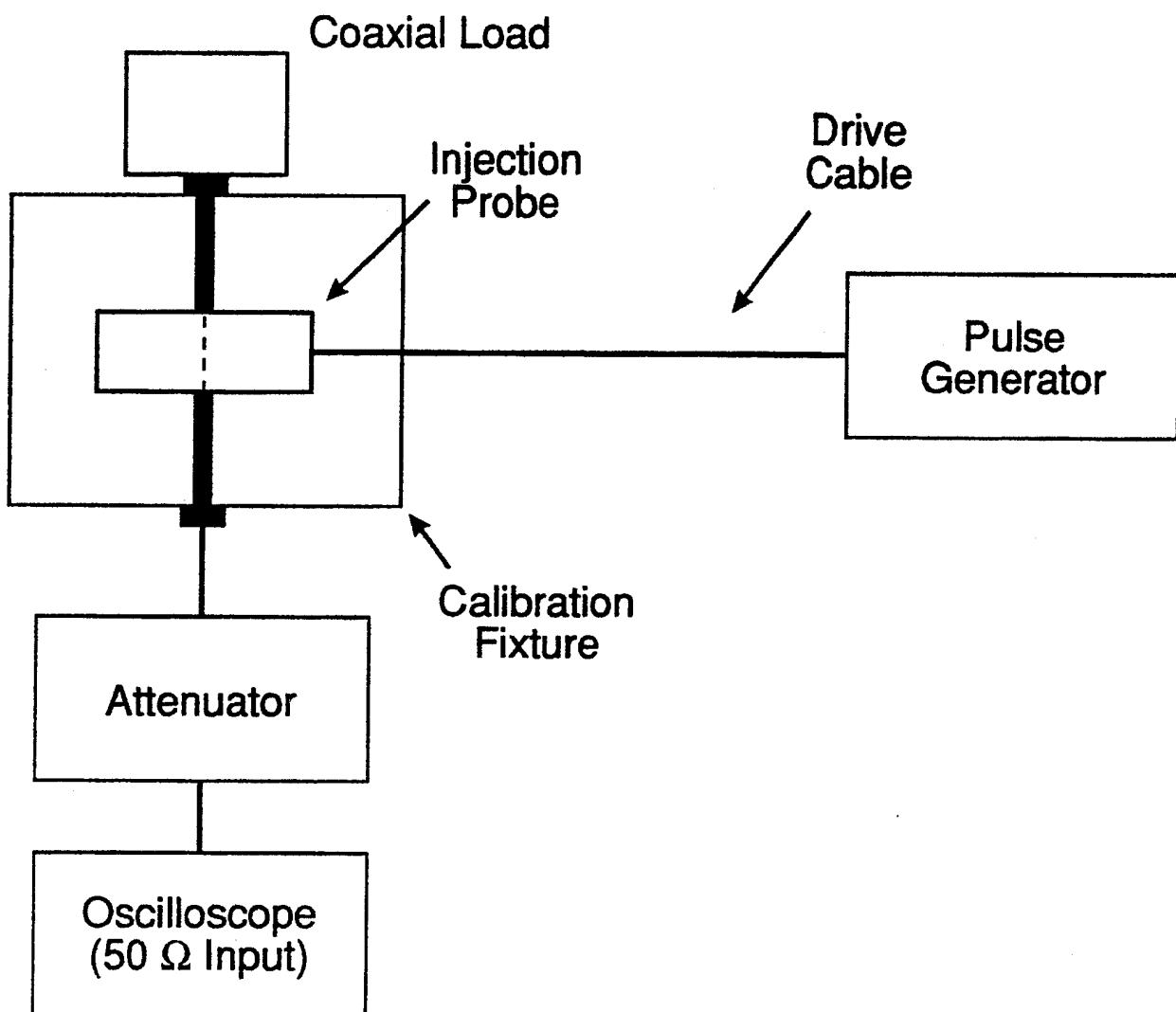
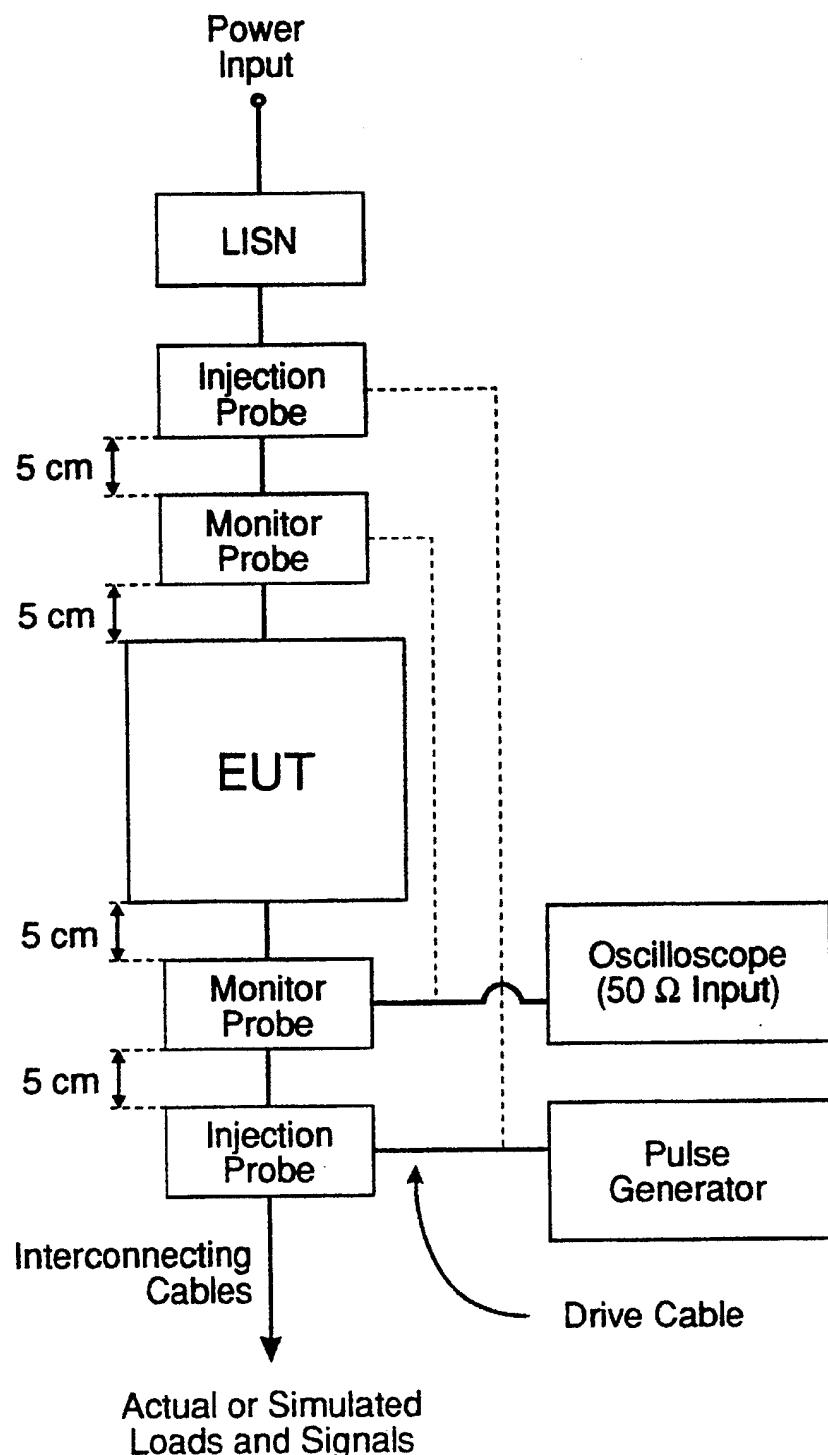


FIGURE CS115-1. Calibration setup.

FIGURE CS115-2. Bulk cable injection.

METHOD CS116

CONDUCTED SUSCEPTIBILITY, DAMPED SINUSOIDAL TRANSIENTS,
CABLES AND POWER LEADS, 10 kHz TO 100 MHz

1. Purpose. This test method is used to verify the ability of the EUT to withstand damped sinusoidal transients coupled onto EUT associated cables and power leads.
2. Test Equipment. The test equipment shall be as follows:
 - a. Damped sinusoid transient generator, ≤ 100 ohm output impedance
 - b. Current injection probe
 - c. Oscilloscope, 50 ohm input impedance
 - d. Calibration fixture: Coaxial transmission line with 50 ohm characteristic impedance, coaxial connections on both ends, and space for an injection probe around the center conductor
 - e. Current probes
 - f. Waveform recording device
 - g. Attenuators
 - h. Measurement receivers
 - i. Power amplifiers
 - j. Coaxial loads
 - k. Signal generators
 - l. Directional couplers
 - m. LISNs
3. Test Setup. The test setup shall be as follows:
 - a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and paragraph 4.8 of the general section of this standard.

- b. Calibration. Configure the test equipment in accordance with Figure CS116-1 for verification of the waveform.
 - c. EUT Testing:
 - (1) Loop Circuit Impedance Characterization.
 - (a) Configure the test equipment in accordance with Figure CS116-2.
 - (b) Place the injection and monitor probes around a cable bundle interfacing with an EUT connector.
 - (c) Locate the monitor probe 5 cm from the connector. If the overall length of the connector and backshell exceeds 5 cm, position the monitor probe as close to the connector's backshell as possible.
 - (d) Position the injection probe 5 cm from the monitor probe.
 - (2) Susceptibility Evaluation.
 - (a) Configure the test equipment as shown in Figure CS116-3.
 - (b) Place the injection and monitor probes around a cable bundle interfacing an EUT connector.
 - (c) Locate the monitor probe 5 cm from the connector. If the overall length of the connector and backshell exceeds 5 cm, position the monitor probe as close to the connector's backshell as possible.
 - (d) Position the injection probe 5 cm from the monitor probe.
4. Test Procedures. The test procedures shall be as follows:
- a. Turn on the measurement equipment and allow sufficient time for stabilization.
 - b. Calibration. Perform the following procedures using the calibration setup for waveform verification.

- (1) Set the frequency of the damped sine generator at 10 kHz.
 - (2) Adjust the amplitude of the signal from the damped sine generator to the level required in MIL-STD-461.
 - (3) Record the damped sine generator settings.
 - (4) Verify that the waveform complies with the requirements of MIL-STD-461.
 - (5) Repeat 4b(2) through 4b(4) for each frequency specified in MIL-STD-461 and those identified in 4c(2).
- c. EUT Testing. Perform the following procedures, using the EUT test setup on each cable bundle interfacing with each connector on the EUT including complete power cables. Also perform tests on each individual power lead.
- (1) Turn on the EUT and allow sufficient time for stabilization.
 - (2) Loop Circuit Impedance Characterization.
 - (a) Set the signal generator to 10 kHz, unmodulated.
 - (b) Apply a power level of approximately 1 mW to the injection probe and record both the power level indicated by measurement receiver B and the induced current level indicated by measurement receiver A.
 - (c) Scan the frequency range from 10 kHz to 100 MHz and record the applied power and induced current level.
 - (d) Adjust the measurement results to amperes for 1 watt of applied power.
 - (e) Identify the resonance frequencies where the maximum and minimum impedances occur.
 - (3) Susceptibility evaluation.
 - (a) Turn on the EUT and measurement equipment to allow sufficient time for stabilization.

- (b) Set the damped sine generator to a test frequency.
- (c) Apply the test signals to each cable or power lead of the EUT sequentially. Slowly increase the damped sinewave generator output level to provide the specified current, but not exceeding the precalibrated generator output level. Record the peak current obtained.
- (d) Monitor the EUT for degradation of performance.
- (e) If susceptibility is noted, determine the level at which the undesirable response is no longer present and verify that it is above the specified requirements.
- (f) Repeat 4c(3) (b) through 4c(3) (e) for each test frequency as specified in MIL-STD-461 and resonance frequencies as determined in 4c(2). Repeat testing in 4c(3) for the power-off condition.

5. Data Presentation. Data presentation shall be as follows:

- a. Provide a list of the frequencies and amplitudes at which the test was conducted for each cable and lead.
- b. Provide amplitude versus frequency plots for the amperes for 1 watt of applied power for each EUT connector interface as determined in 4c(2) (d).
- c. Provide data on any susceptibility thresholds and the associated frequencies which were determined for each connector and power lead.
- d. Provide indications of compliance with the MIL-STD-461 requirements for the susceptibility evaluation specified in 4c for each interface connector.
- e. Provide oscilloscope photographs of injected waveforms with test data.

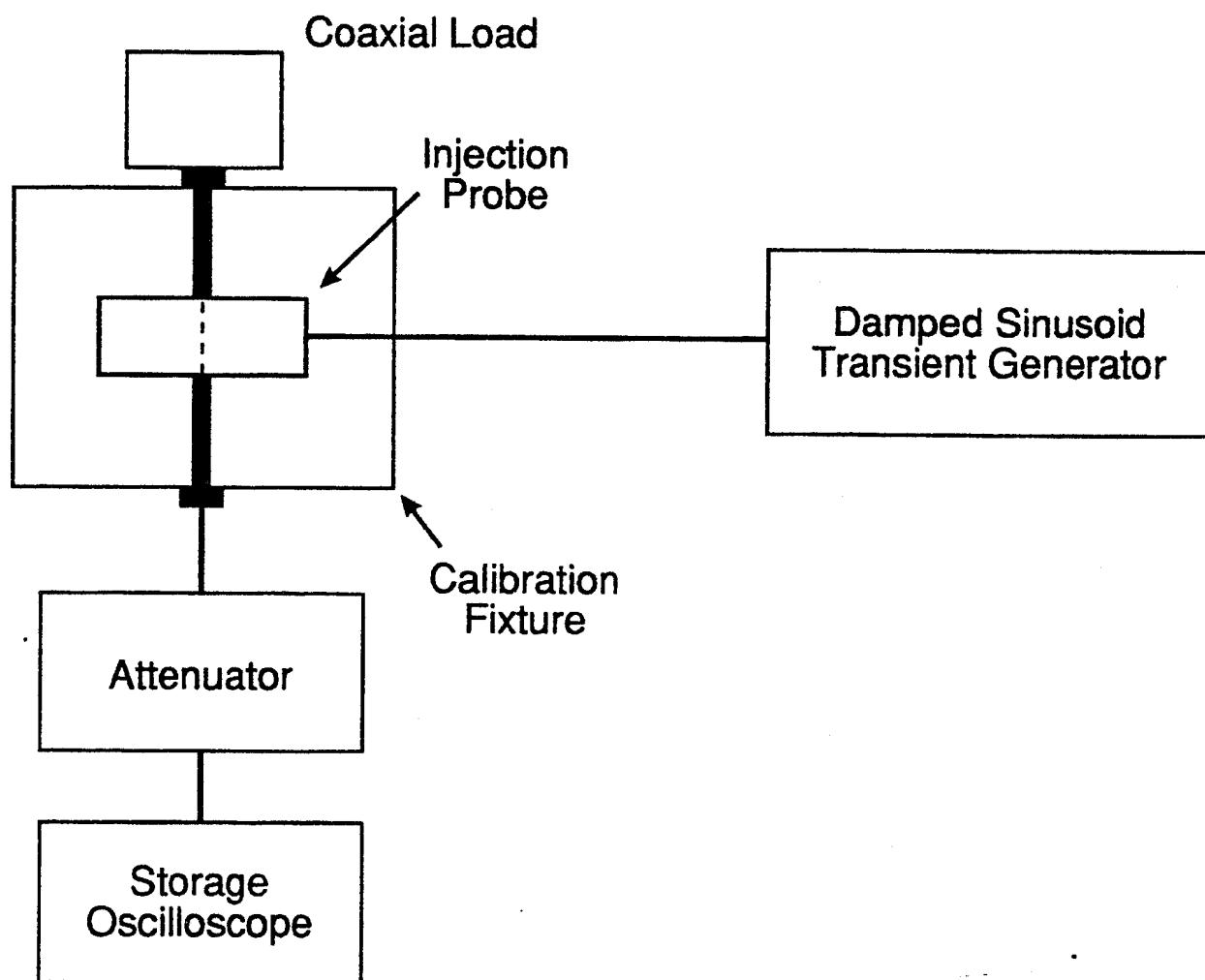
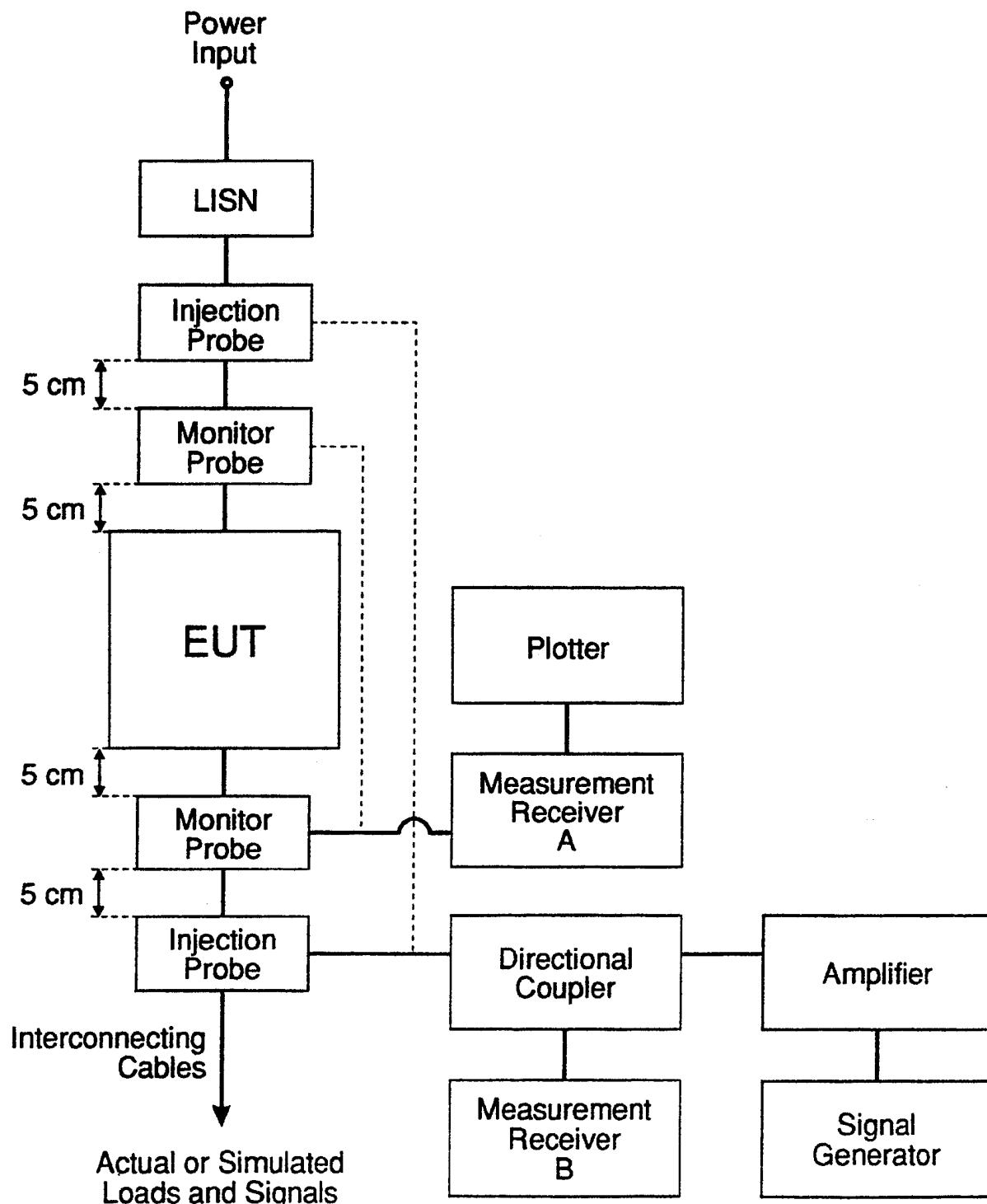


FIGURE CS116-1. Typical test setup for calibration of test waveform.

FIGURE CS116-2. Loop circuit impedance characterization.

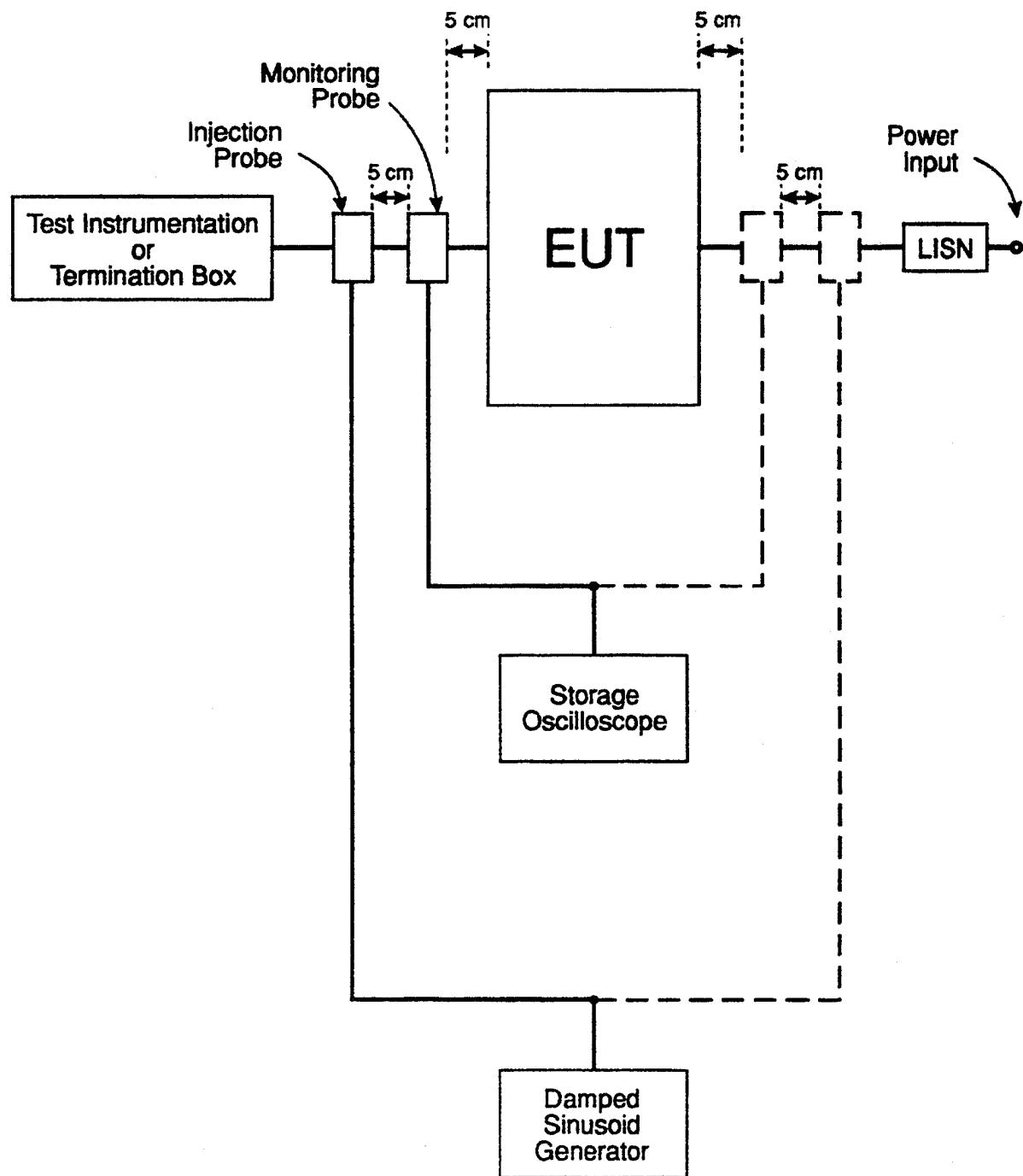


FIGURE CS116-3. Typical set up for bulk cable injection of damped sinusoidal transients.

METHOD RE101

RADIATED EMISSIONS, MAGNETIC FIELD, 30 Hz TO 100 kHz

1. Purpose. This test method is to verify that the magnetic field emissions from the EUT and its associated cabling do not exceed specified requirements.

2. Test Equipment. The test equipment shall be as follows:

a. Measurement receivers

b. Data recording device

c. Loop sensor having the following specifications:

(1) Diameter: 13.3 cm

(2) Number of turns: 36

(3) Wire: 7-41 Litz (7 strand, No. 41 AWG)

(4) Shielding: Electrostatic

(5) Correction factor: To convert measurement receiver readings expressed in decibels above one microvolt ($dB\mu V$) to decibels above one picotesla ($dB\mu T$), add the factor shown in Figure RE101-1.

d. LISNs

3. Test Setup. The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and paragraph 4.8 of the general section of this standard.

b. Calibration. Configure the measurement setup as shown in Figure RE101-2.

c. EUT Testing. Configure the measurement receiving loop and EUT as shown in Figure RE101-3.

4. Test Procedures. The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow sufficient time for stabilization.
- b. Calibration.
 - (1) Apply a calibrated signal level, which is 6 dB below the MIL-STD-461 limit, at a frequency of 50 kHz. Tune the measurement receiver to a center frequency of 50 kHz. Record the measured level.
 - (2) Verify that the measurement receiver indicates a level within ± 3 dB of the injected signal level.
 - (3) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
- c. EUT Testing.
 - (1) Turn on the EUT and allow sufficient time for stabilization.
 - (2) Locate the loop sensor 7 cm from the EUT face or cable being probed. Orient the plane of the loop sensor parallel to the EUT faces and parallel to the axis of cables.
 - (3) Scan the measurement receiver over the applicable frequency range to locate the frequencies of maximum radiation, using the bandwidths and minimum measurement times of the general section of this standard.
 - (4) Tune the measurement receiver to one of the frequencies or band of frequencies identified in 4c(3) above.
 - (5) Monitor the output of the measurement receiver while moving the loop sensor (maintaining the 7 cm spacing) over the face of the EUT or along the cable. Note the point of maximum radiation for each frequency identified in 4c(4).
 - (6) At 7 cm from the point of maximum radiation, orient the plane of the loop sensor to give a maximum

reading on the measurement receiver and record the reading.

- (7) Move the loop sensor away from the EUT face or the cable being probed to a distance of 50 cm and record the reading on the measurement receiver.
- (8) Repeat 4c(4) through 4c(7) for at least two frequencies of maximum radiation per octave of frequencies below 200 Hz and for at least three frequencies of maximum radiation per octave above 200 Hz.
- (9) Repeat 4c(2) through 4c(8) for each face of the EUT and for each cable connected to the EUT.

5. Data Presentation. Data presentation shall be as follows:

- a. Provide graphs or a tabular listing of each measurement frequency, mode of operation, distance from the EUT, measured magnetic field, and magnetic field limit level for both the 7 cm and 50 cm distances.

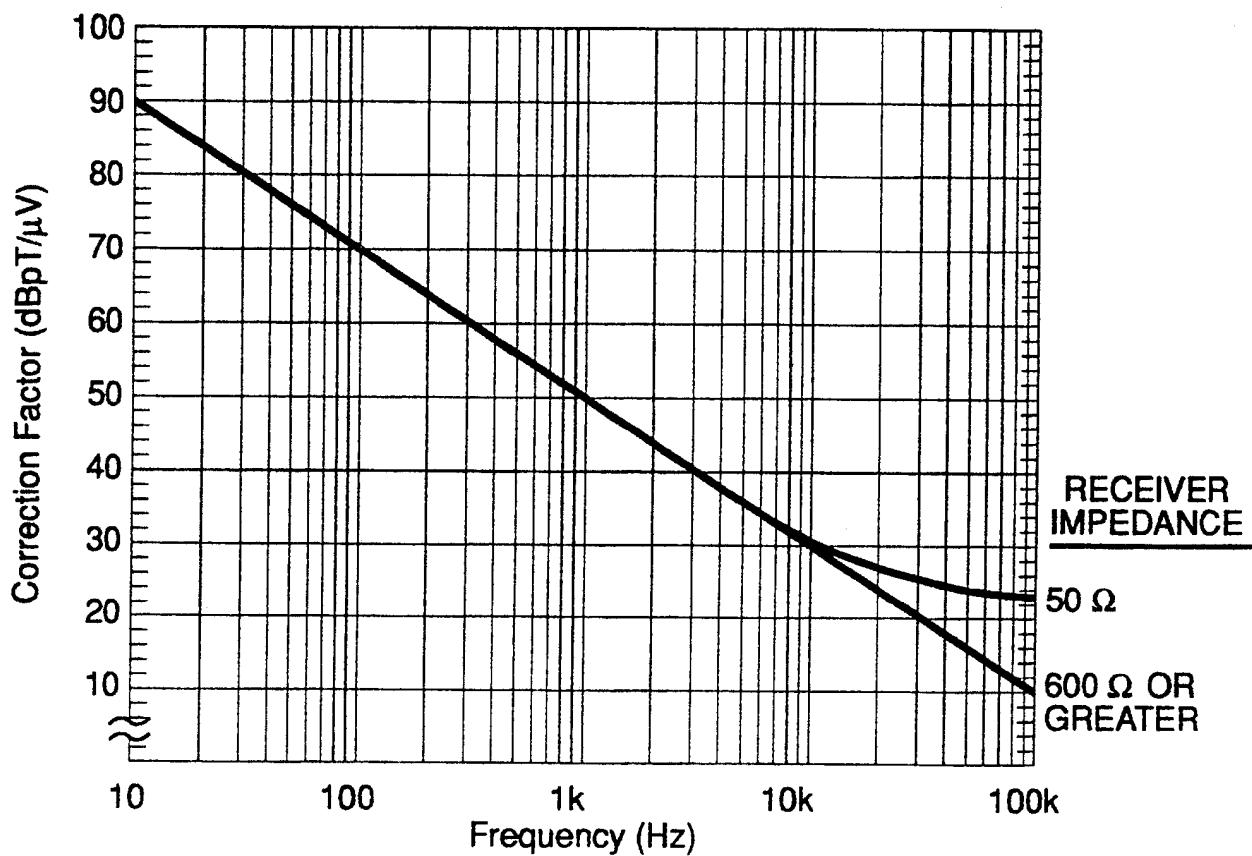


FIGURE RE101-1. Loop sensor correction factor.

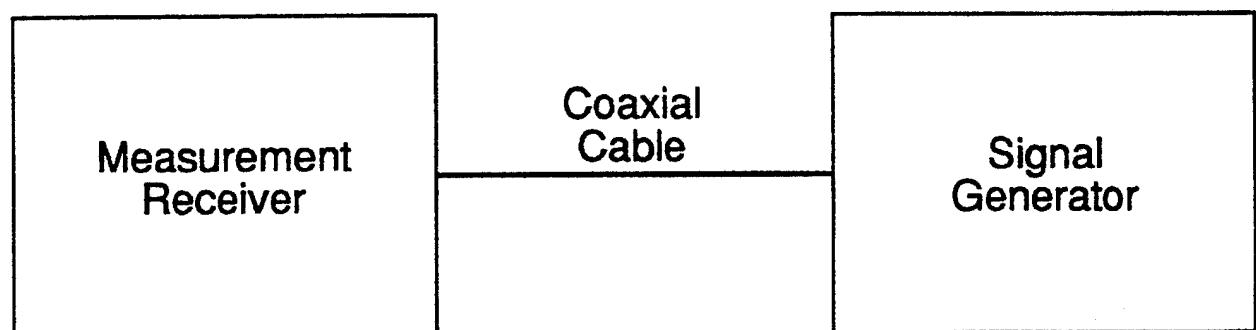


FIGURE RE101-2. Calibration configuration.

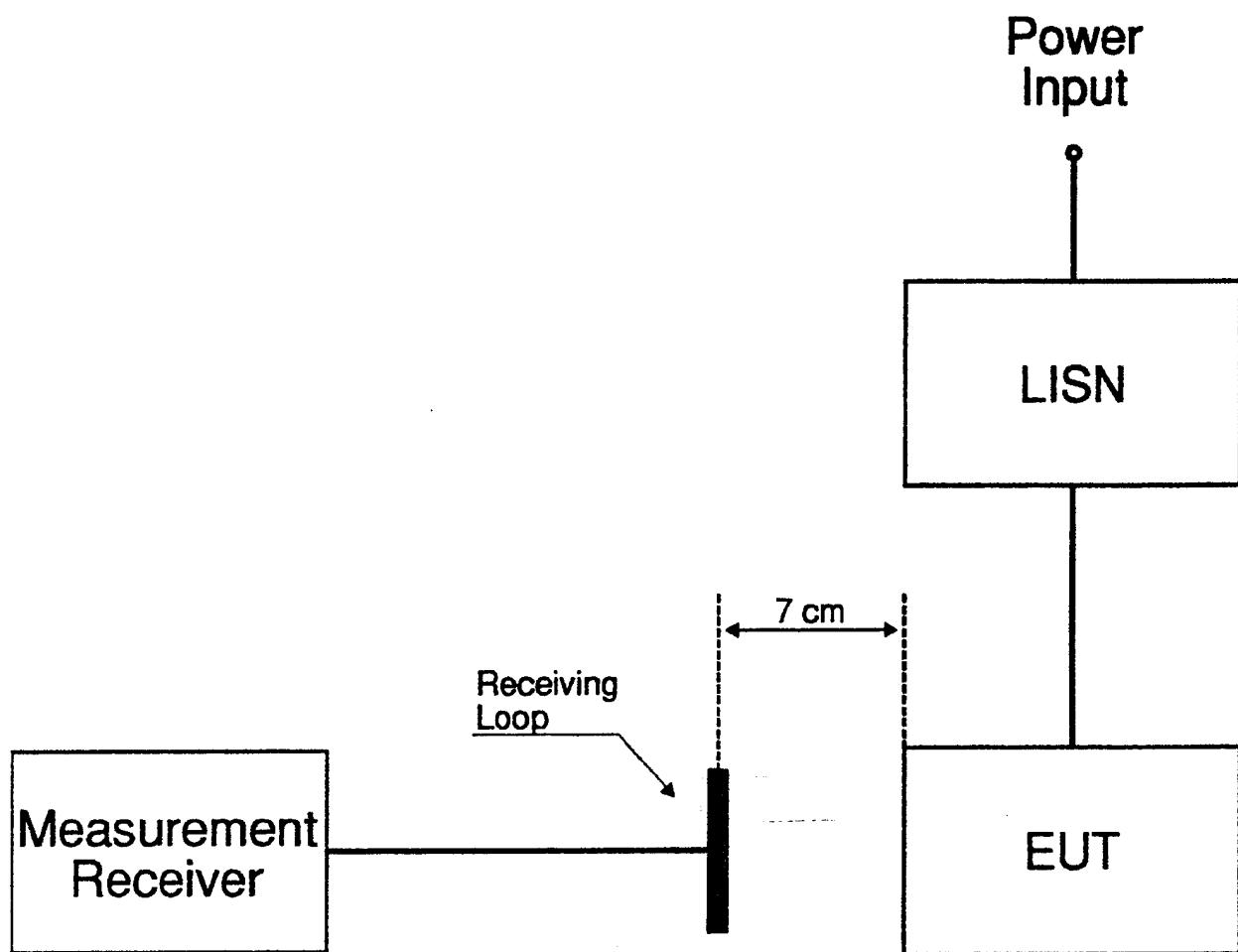


FIGURE RE101-3. Typical Test Setup for Radiated Emissions, Magnetic Field, 30 Hz to 100 kHz.

METHOD RE102

RADIATED EMISSIONS, ELECTRIC FIELD, 10 kHz TO 18 GHz

1. Purpose. This test method is used to verify that electric field emissions from the EUT and its associated cabling do not exceed specified requirements.

2. Test Equipment. The test equipment shall be as follows:

a. Measurement receivers

b. Data recording device

c. Antennas

(1) 10 kHz to 30 MHz, 104 cm rod with impedance matching network

(a) When the impedance matching network includes a preamplifier (active rod), observe the overload precautions in 4.7.3 of the general section of this standard.

(b) Use a square counterpoise measuring at least 60 cm on a side.

(2) 30 MHz to 200 MHz, Biconical, 137 cm tip to tip

(3) 200 MHz to 18 GHz, Double ridge horns

d. Signal generators

e. Stub radiator

f. Capacitor, 10 pF

g. LISNs

3. Test Setup. The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figures 1 through 5 and paragraph 4.8 of the general section of this standard. Ensure that the EUT is oriented such that the surface which produces the maximum radiated emissions is toward the measurement antenna.

- b. Calibration. Configure the test equipment as shown in Figure RE102-1.
- c. EUT testing.
 - (1) For shielded room measurements, electrically bond the rod antenna counterpoise to the ground plane using a solid metal sheet the same width as the counterpoise. The maximum DC resistance between the counterpoise and the ground plane shall be 2.5 milliohms. For bench top setups using a metallic ground plane, bond the counterpoise to this ground plane. Otherwise, bond the counterpoise to the floor ground plane. For measurements outside a shielded enclosure, electrically bond the counterpoise to earth ground.
 - (2) Antenna Positioning.
 - (a) Determine the test setup boundary of the EUT and associated cabling for use in positioning of antennas.
 - (b) Use the physical reference points on the antennas shown in Figure RE102-2 for measuring heights of the antennas and distances of the antennas from the test setup boundary.
 - 1. Position antennas 1 meter from the front edge of the test setup boundary for all setups.
 - 2. Position antennas other than the 104 cm rod antenna 120 cm above the floor ground plane.
 - 3. Insure that no part of any antenna is closer than 1 meter from the walls and 0.5 meter from the ceiling of the shielded enclosure.
 - 4. For test setups using bench tops, additional positioning requirements for the rod antenna and distance above the bench ground plane are shown in Figure RE102-2.
 - 5. For free standing setups, electrically bond and mount the 104 cm rod antenna matching network to the floor ground plane without a separate counterpoise.

(c) The number of required antenna positions depends on the size of the test setup boundary and the number of enclosures included in the setup.

1. For testing below 200 MHz, use the following criteria to determine the individual antenna positions.

- a. For setups with the side edges of the boundary 3 meters or less, one position is required and the antenna shall be centered with respect to the side edges of the boundary.
- b. For setups with the side edges of the boundary greater than 3 meters, use multiple antenna positions at spacings as shown in Figure RE102-3. Determine the number of antenna positions (N) by dividing the edge-to-edge boundary distance (in meters) by 3 and rounding up to an integer.

2. For testing from 200 MHz up to 1 GHz, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

3. For testing at 1 GHz and above, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

4. Test Procedures. The test procedures shall be as follows:

- a. Verify that the ambient requirements specified in 4.4 of the general section of this standard are met. Take plots of the ambient when required by the referenced paragraph.
- b. Turn on the measurement equipment and allow a sufficient time for stabilization.
- c. Using the system check path of Figure RE102-1, perform the following evaluation of the overall measurement

system from each antenna to the data output device at the highest measurement frequency of the antenna. For rod antennas that use passive matching networks, the evaluation shall be performed at the center frequency of each band.

- (1) Apply a calibrated signal level, which is 6 dB below the MIL-STD-461 limit (limit minus antenna factor), to the coaxial cable at the antenna connection point.
 - (2) Scan the measurement receiver in the same manner as a normal data scan. Verify that the data recording device indicates a level within ± 3 dB of the injected signal level.
 - (3) For the 104 cm rod antenna, remove the rod element and apply the signal to the antenna matching network through a 10 pF capacitor connected to the rod mount.
 - (4) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
- d. Using the measurement path of Figure RE102-1, perform the following evaluation for each antenna to demonstrate that there is electrical continuity through the antenna.
- (1) Radiate a signal using an antenna or stub radiator at the highest measurement frequency of each antenna.
 - (2) Tune the measurement receiver to the frequency of the applied signal and verify that a received signal of appropriate amplitude is present.
- e. Turn on the EUT and allow sufficient time for stabilization.
- f. Using the measurement path of Figure RE102-1, determine the radiated emissions from the EUT and its associated cabling.
- (1) Scan the measurement receiver for each applicable frequency range, using the bandwidths and minimum measurement times in the general section of this standard.
 - (2) Above 30 MHz, orient the antennas for both horizontally and vertically polarized fields.

- (3) Take measurements for each antenna position determined under 3c(2)(c) above.

5. Data Presentation. Data presentation shall be as follows:

- a. Continuously and automatically plot amplitude versus frequency profiles. Manually gathered data is not acceptable except for plot verification.
- b. Display the applicable limit on each plot.
- c. Provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.
- d. Provide plots for both the measurement and system check portions of the procedure.
- e. Provide a statement verifying the electrical continuity of the measurement antennas as determined in 4d.

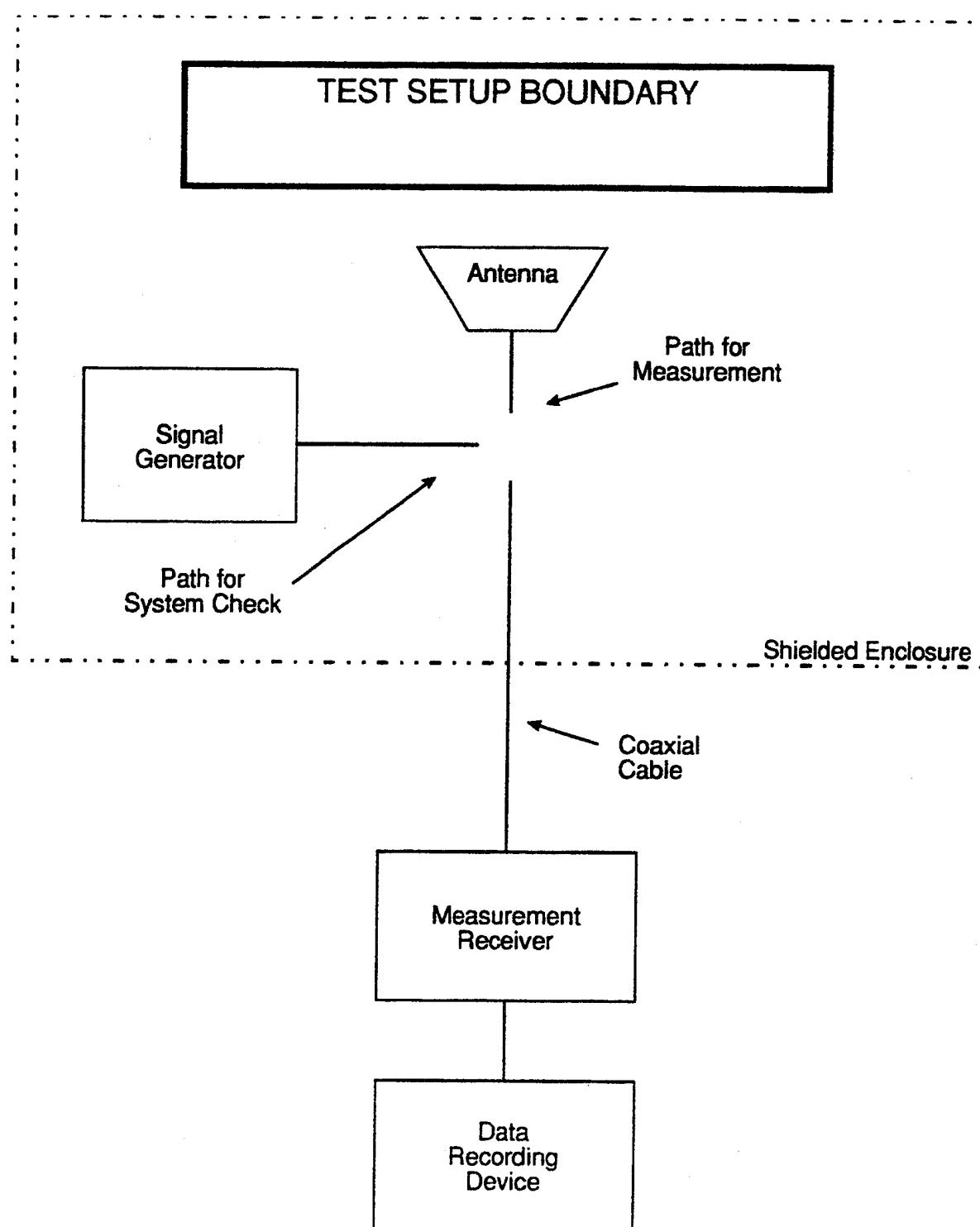
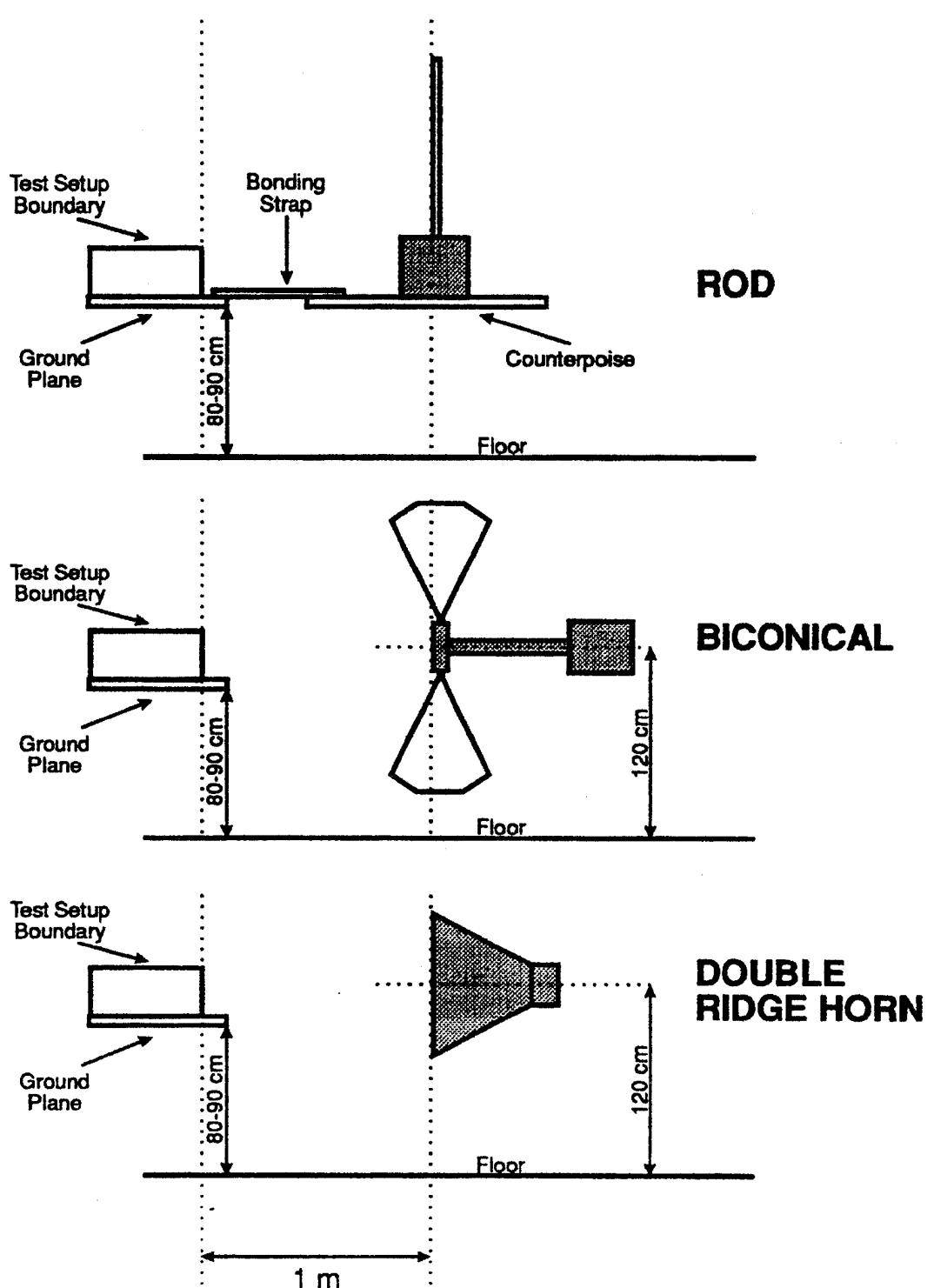
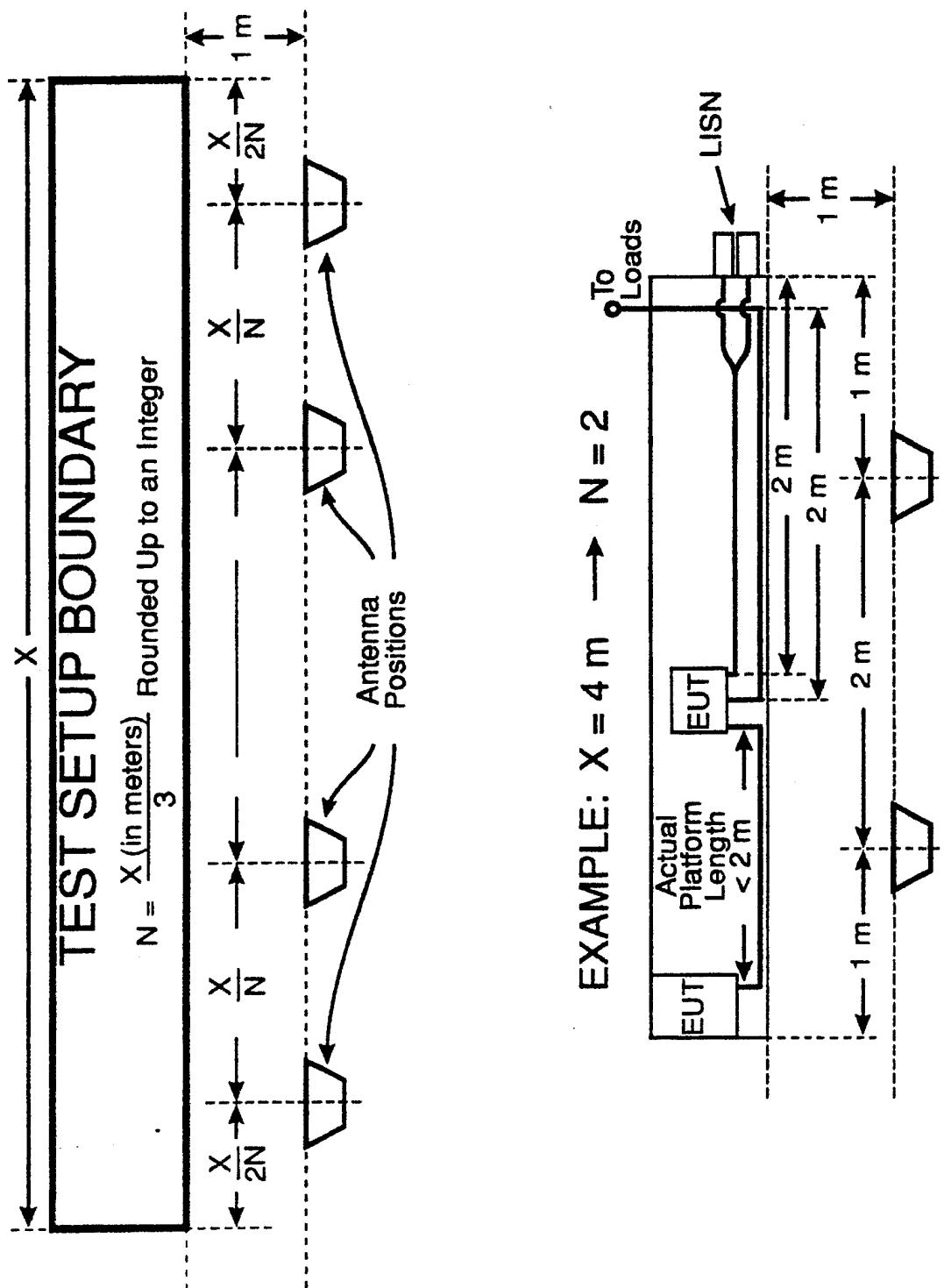


FIGURE RE102-1. Basic test setup.

FIGURE RE102-2. Antenna positioning.

FIGURE RE102-3. Multiple antenna positions.

METHOD RE103

RADIATED EMISSIONS, ANTENNA SPURIOUS AND HARMONIC OUTPUTS,
10 kHz TO 40 GHz

1. Purpose. This test method is used to verify that radiated spurious and harmonic emissions from transmitters do not exceed the specified requirements.

2. Test Equipment. The test equipment shall be as follows:

- a. Measurement receiver
- b. Attenuators
- c. Antennas
- d. Rejection networks
- e. Signal generators
- f. Power monitor

3. Test Setup. It is not necessary to maintain the basic test setup for the EUT as shown and described in figures 1 through 5 and paragraph 4.8 of the general section of this standard. The test setup shall be as follows:

- a. Calibration. Configure the test setup for the signal check path shown in Figure RE103-1 or RE103-2 as applicable.
- b. EUT Testing. Configure the test setup for the measurement path shown in Figure RE103-1 or RE103-2 as applicable.

4. Test Procedures. The test procedures shall be as follows:

- a. The measurements must be performed in the far-field of the transmitting frequency. Consequently, the far-field test distance must be calculated prior to performing the test using the relationships below:

R = distance between transmitter antenna and receiver antenna.

D = maximum physical dimension of transmitter antenna.

d = maximum physical dimension of receiver antenna.

λ = wavelength of frequency of the transmitter.

All dimensions are in meters.

For transmitter frequencies less than or equal to 1.24 GHz, the greater distance of the following relationships shall be used:

$$R = 2D^2/\lambda$$

$$R = 3\lambda$$

For transmitter frequencies greater than 1.24 GHz, the separation distance shall be calculated as follows:

$$\text{For } 2.5 D < d \text{ use } R = 2D^2/\lambda$$

$$\text{For } 2.5 D \geq d \text{ use } R = (D+d)^2/\lambda$$

b. Turn on the measurement equipment and allow sufficient time for stabilization.

c. Calibration.

(1) Apply a known calibrated signal level from the signal generator through the system check path at a midband fundamental frequency (f_0) in accordance with the general section of this standard.

(2) Scan the measurement receiver in the same manner as a normal data scan. Verify the measurement receiver detects a level within ± 3 dB of the expected signal.

(3) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the test.

(4) Repeat 4c(1) through 4c(3) for two other frequencies over the frequency range of test.

d. EUT Testing.

(1) Turn on the EUT and allow a sufficient time for stabilization.

- (2) Tune the EUT to the desired test frequency and use the measurement path to complete the rest of this procedure.
- (3) Tune the test equipment to the measurement frequency (f_0) of the EUT and adjust for maximum indication.
- (4) Measure the modulated transmitter power output P , using a power monitor while keying the transmitter. Convert this power level to units of dB relative to 1 watt (dBW). Calculate the Effective Radiated Power (ERP) by adding the EUT antenna gain to this value. Record the resulting level for comparison with that obtained in 4d(6).
- (5) Key the transmitter with desired modulation. Tune the measurement receiver for maximum output indication at the transmitted frequency. If either or both of the antennas have directivity, align both in elevation and azimuth for maximum indication. Verbal communication between sites via radiotelephone will facilitate this process. Record the resulting maximum receiver meter reading and the measurement receiver bandwidth.
- (6) Calculate the transmitter ERP in dBW, based on the receiver meter reading V , using the following equation:

$$\text{ERP} = V + 20 \log R + AF - 135$$

where:

V = reading on the measurement receiver in $\text{dB}\mu\text{V}$

R = distance between transmitter and receiver antennas in meters

AF = antenna factor of receiver antenna in dB (1/m)

Compare this calculated level to the measured level recorded in 4d(4). The compared results should agree within ± 3 dB. If the difference exceeds ± 3 dB, check the test setup for errors in measurement distance, amplitude calibration, power monitoring of the transmitter, frequency tuning or drift and antenna boresight alignment. Assuming that the results are within the ± 3 dB tolerance, the ERP becomes the reference for which amplitudes of spurious and harmonics will be compared to determine compliance with standard limits.

- (7) With the rejection network filter connected and tuned to f_o , scan the measurement receiver over the frequency range of test to locate spurious and harmonic transmitted outputs. It may be necessary to move the measuring system antenna in elevation and azimuth at each spurious and harmonic output to assure maximum levels are recorded. Maintain the same measurement receiver bandwidth used to measure the fundamental frequency in 4d(5).
- (8) Verify that spurious outputs are from the EUT and not spurious responses of the measurement system or the test site ambient.
- (9) Calculate the ERP of each spurious output. Include all correction factors for cable loss, amplifier gains, filter loss, and attenuator factors.
- (10) Repeat 4d(2) through 4d(9) for other f_o of the EUT.

5. Data Presentation. Data presentation shall be as follows:

- a. Provide tabular data showing fundamental frequency (f_o) and frequency of all harmonics and spurious emissions measured, the measured power monitor level and the calculated ERP of the fundamental frequency, the ERP of all spurious and harmonics emissions measured, dB down levels, and all correction factors including cable loss, attenuator pads, amplifier gains, insertion loss of rejection networks and antenna gains.
- b. The relative dB down level is determined by subtracting the level in 4d(6) from that recorded in 4d(9).

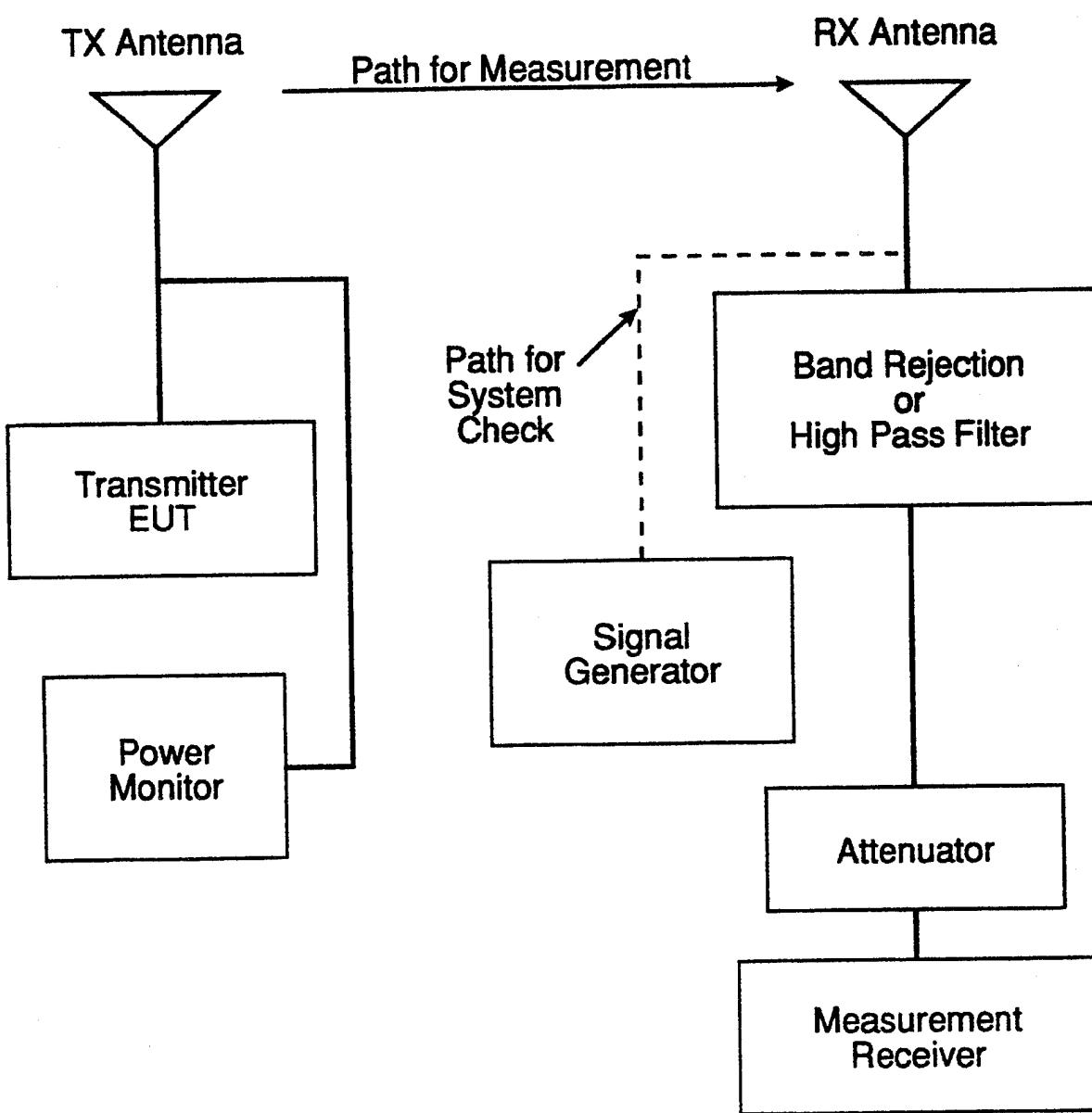


FIGURE RE103-1. Calibration and test setup for radiated harmonics and spurious emissions, 10 kHz to 1 GHz.

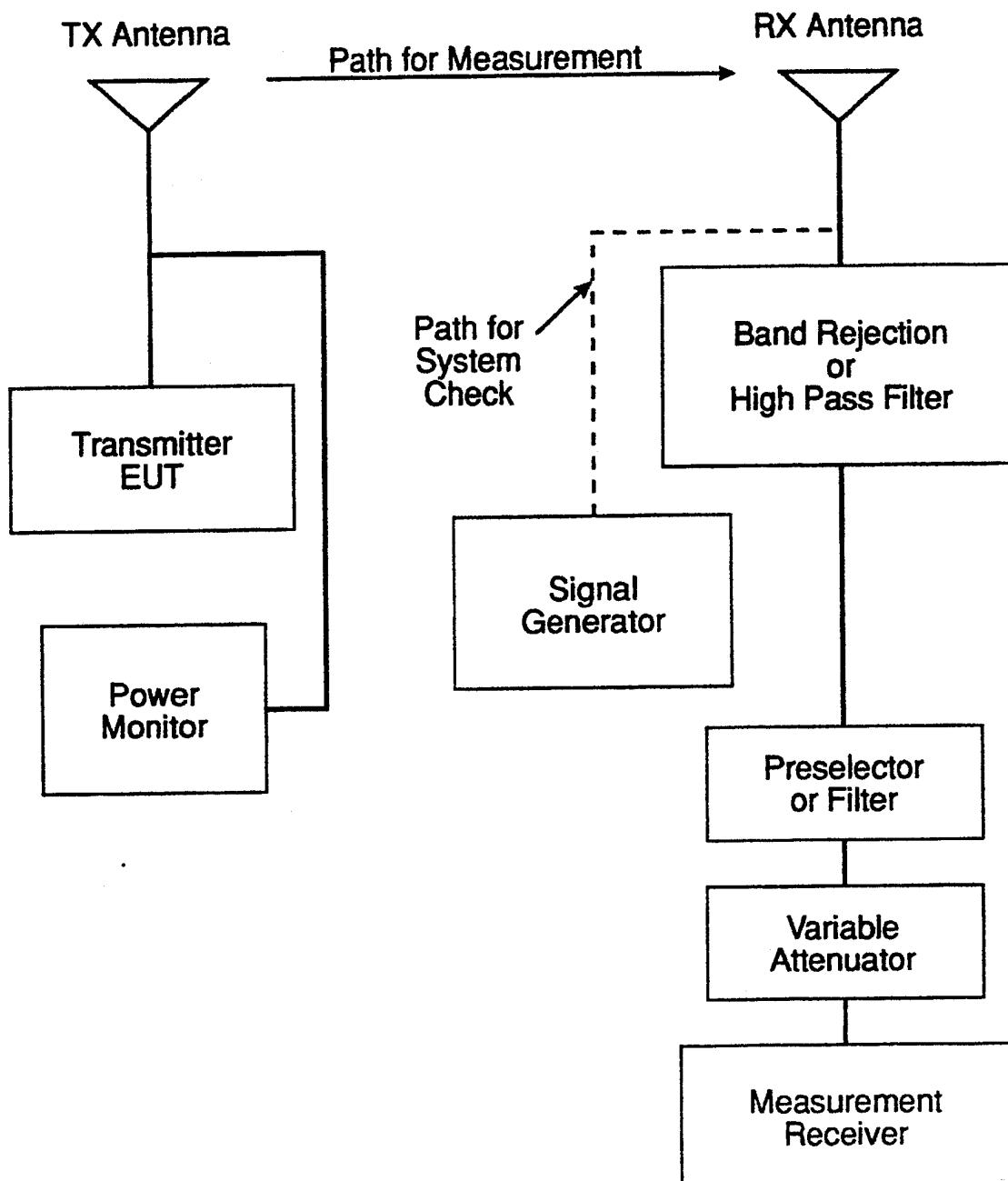


FIGURE RE103-2. Calibration and test setup for radiated harmonics and spurious emissions, 1 GHz to 40 GHz.

METHOD RS101

RADIATED SUSCEPTIBILITY, MAGNETIC FIELD, 30 Hz TO 100 kHz

1. Purpose. This test method is to verify the ability of the EUT to withstand radiated magnetic fields.
2. Test Equipment. The test equipment shall be as follows:

a. Signal source

b. Radiating loop having the following specifications:

(1) Diameter: 12 cm

(2) Number of turns: 20

(3) Wire: No. 12 insulated copper

(4) Magnetic flux density: 9.5×10^7 pT/ampere of applied current at a distance of 5 cm from the plane of the loop.

c. Loop sensor having the following specifications:

(1) Diameter: 4 cm

(2) Number of turns: 51

(3) Wire: 7-41 Litz (7 Strand, No. 41 AWG)

(4) Shielding: Electrostatic

(5) Correction Factor: To convert measurement receiver readings expressed in decibels above one microvolt ($\text{dB}\mu\text{V}$) to decibels above one picotesla ($\text{dB}\mu\text{T}$), add the factor shown in figure RS101-1.

d. Measurement receiver or narrowband voltmeter

e. Current probe

f. LISNs

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11 January 1993

3. Test Setup. The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and paragraph 4.8 of the general section of this standard.
- b. Calibration.

(1) Configure the measurement equipment, radiating loop, and loop sensor as shown in Figure RS101-2.

c. EUT Testing.

(1) Configure the test as shown in Figure RS101-3.

4. Test Procedures. The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow sufficient time for stabilization.

b. Calibration.

(1) Set the signal source to a frequency of 1 kHz and adjust the output to provide a magnetic flux density of 110 dB above one picotesla as determined by the reading obtained on measurement receiver A and the relationship given in 2b(4).

(2) Measure the voltage output from the loop sensor.

(3) Verify that the output on measurement receiver B is 42 dB μ V \pm 3 dB and record this value in the appropriate space on the data sheet.

c. EUT Testing.

(1) Turn on the EUT and allow sufficient time for stabilization.

(2) Select test frequencies as follows:

(a) Position the radiating loop 5 cm from one face of the EUT. The plane of the loop shall be parallel to the plane of the EUT's surface.

(b) Supply the loop with sufficient current to produce magnetic field strengths at least 10 dB

greater than the applicable limit in MIL-STD-461 but not to exceed 15 amps (183 dB_PT).

- (c) Scan the applicable frequency range specified in MIL-STD-461. Scan rates up to 3 times faster than the rates specified in Table III are acceptable.
 - (d) If susceptibility is noted, select no less than three test frequencies per octave at those frequencies where the maximum indications of susceptibility are present.
 - (e) Reposition the loop successively to a location in each 30 by 30 cm area on each face of the EUT and at each electrical interface connector, and repeat 4c(2)(c) and 4c(2)(d) to determine locations and frequencies of susceptibility.
 - (f) From the total frequency data where susceptibility was noted in 4c(2)(c) through 4c(2)(e), select three frequencies per octave over the applicable frequency range in MIL-STD-461.
- (3) At each frequency determined in 4c(2)(f), apply a current to the radiating loop that corresponds to the applicable limit in MIL-STD-461. Move the loop to search for possible locations of susceptibility with particular attention given to the locations determined in 4c(2)(e) while maintaining the loop 5 cm from the EUT surface, cable, or connector. Verify that susceptibility is not present.

5. Data Presentation. Data presentation shall be as follows:

- a. Provide tabular data showing verification of the calibration of the radiating loop in 4a.
- b. Provide tabular data, diagrams, or photographs showing the applicable test frequencies and locations determined in 4c(2)(e) and 4c(2)(f).
- c. Provide graphical or tabular data showing frequencies and threshold levels of susceptibility.

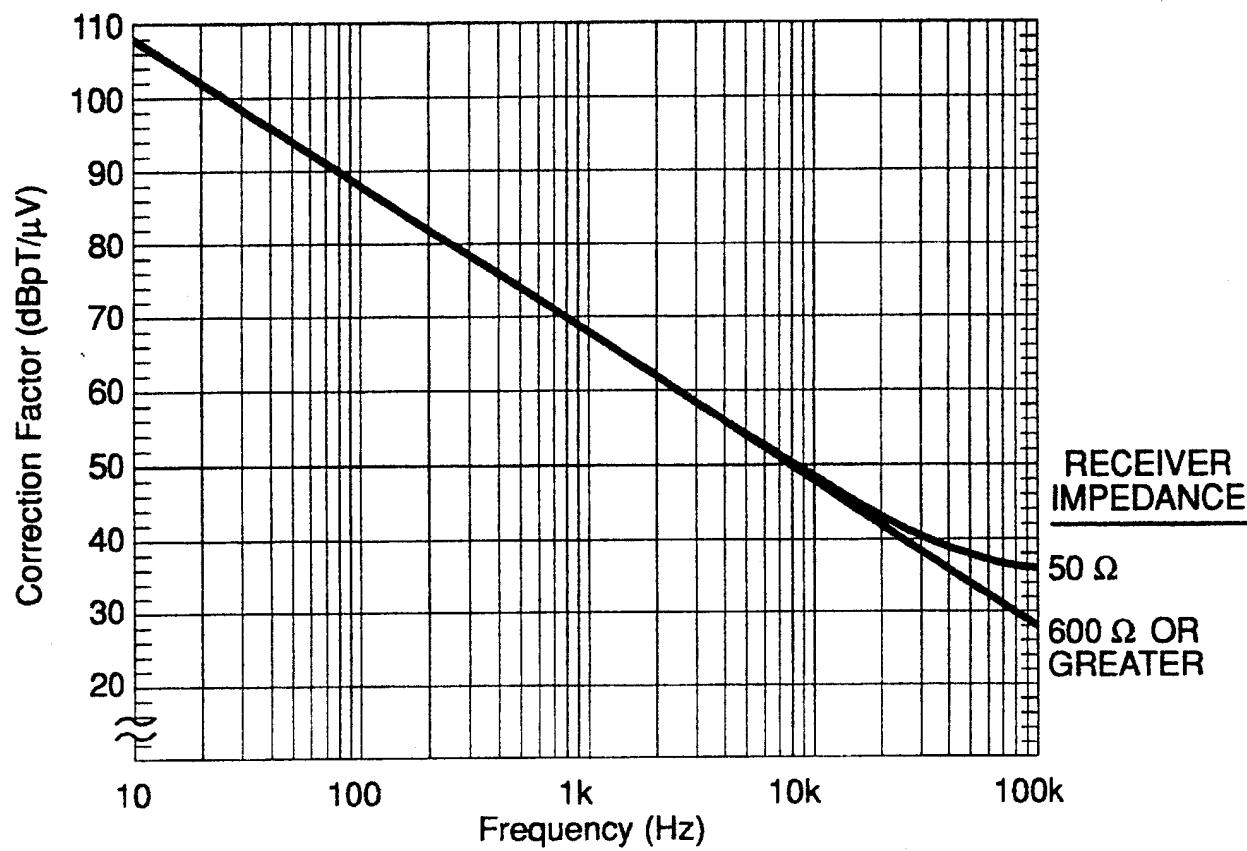


FIGURE RS101-1. Loop sensor correction factor.

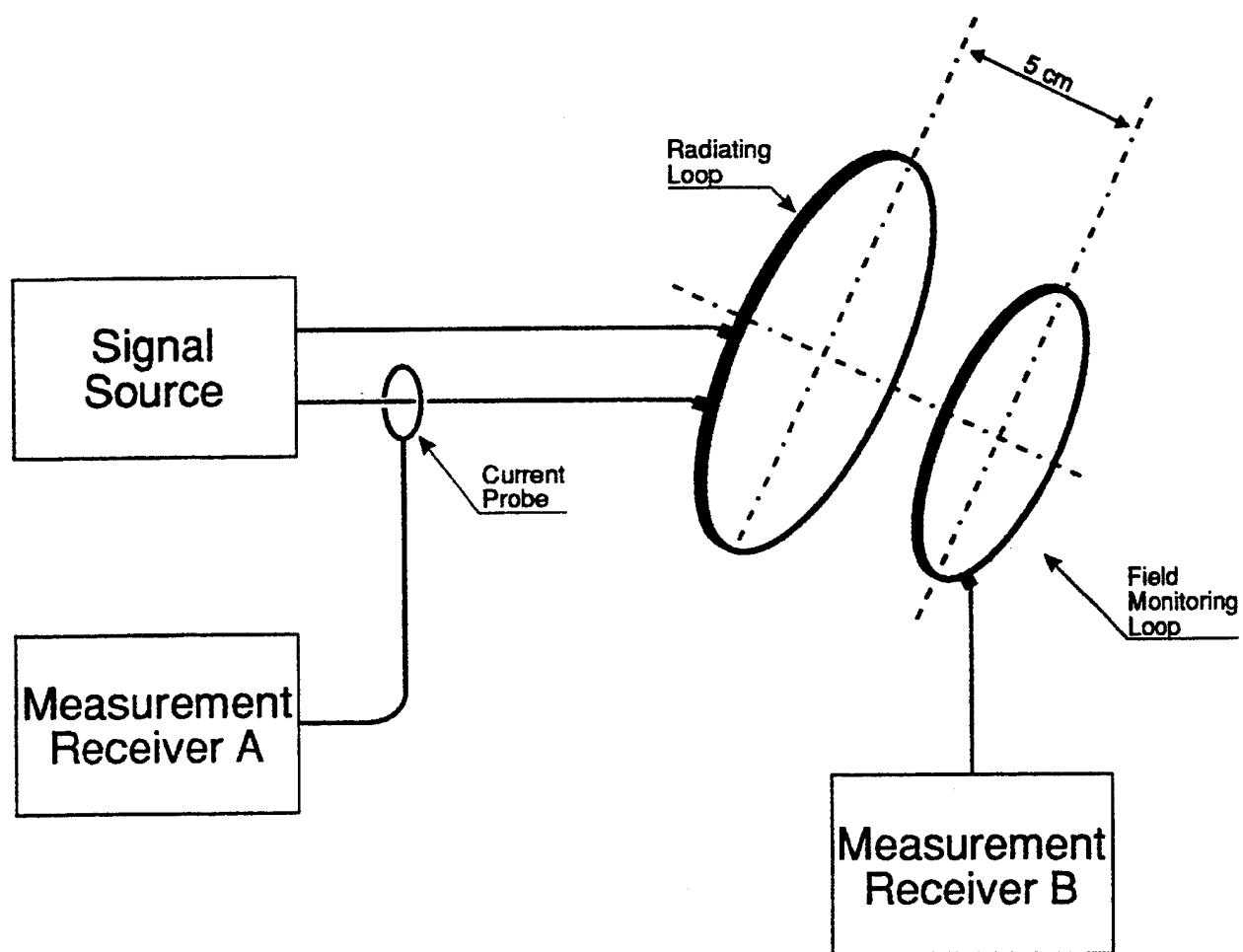


FIGURE RS101-2. Calibration of the radiating system.

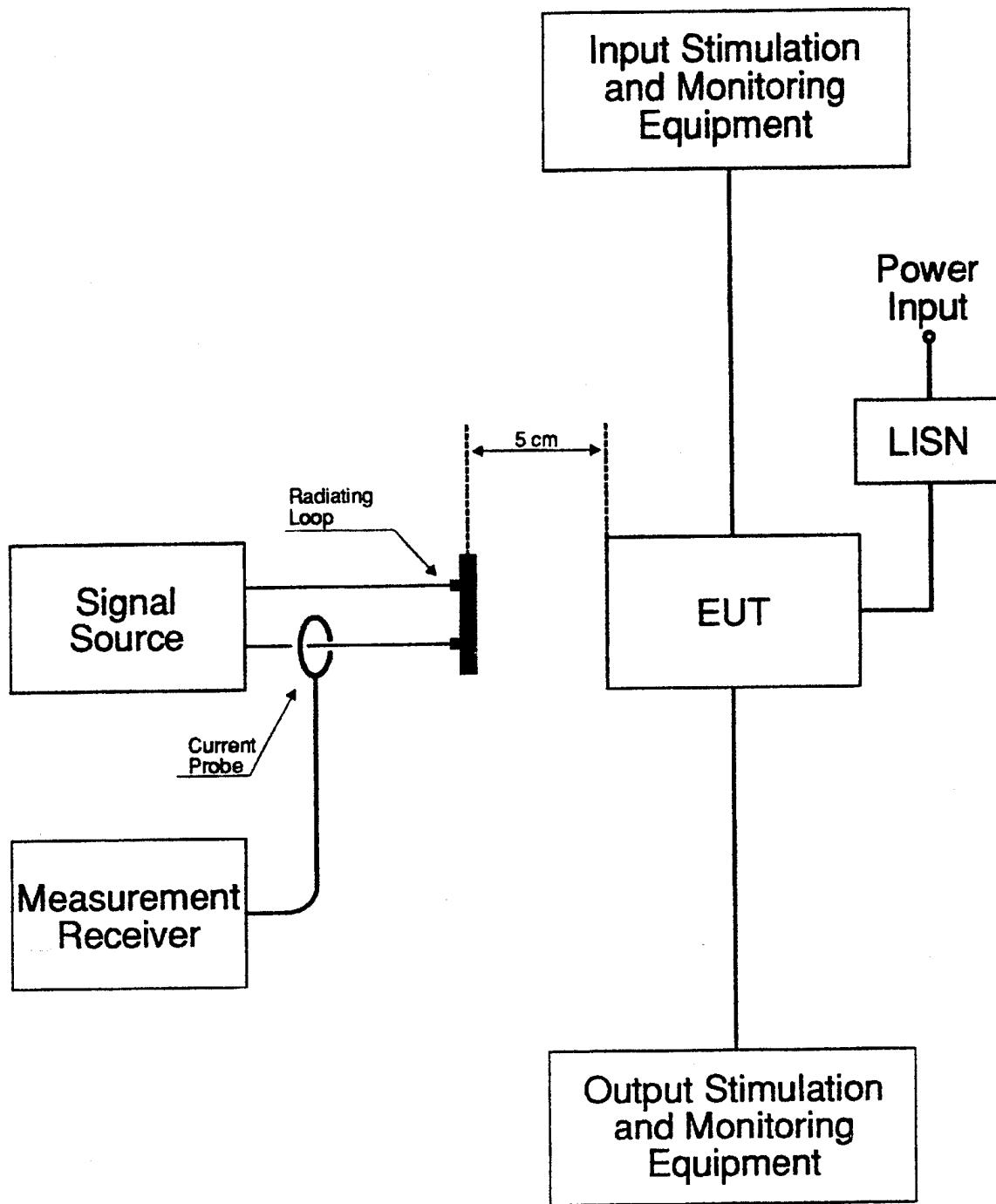


FIGURE RS101-3. Typical test setup for radiated susceptibility. Magnetic field, 30 Hz to 50 kHz.

METHOD RS103

RADIATED SUSCEPTIBILITY, ELECTRIC FIELD, 10 kHz TO 40 GHz

1. Purpose. This test method is used to verify the ability of the EUT and associated cabling to withstand electric fields.

2. Test Equipment. The test equipment shall be as follows:

- a. Signal generators
- b. Power amplifiers
- c. Receive antennas
 - (1) 1 GHz to 10 GHz, double ridge horns
 - (2) 10 GHz to 40 GHz, other antennas as approved by the procuring activity
- d. Transmit antennas
- e. Electric field sensors (physically small - electrically short)
- f. Measurement receiver
- g. Power meter
- h. Directional coupler
- i. Attenuator
- j. Data recording device
- k. LISNs

3. Test Setup. The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 1 through 5 and paragraph 4.8 of the general section of this standard.
- b. For electric field calibration, electric field sensors are required from 10 kHz to 1 GHz. Either field sensors or receive antennas may be used above 1 GHz (see 2c and 2e).

c. Configure test equipment as shown in Figure RS103-1.

d. Calibration.

(1) Placement of electric field sensors (see 3b).

Position sensors 1 meter from, and directly opposite, the transmit antenna as shown in Figures RS103-2 and RS103-3. Do not place sensors directly at corners or edges of EUT components.

(2) Placement of receive antennas (see 3b). Prior to placement of the EUT, position the receive antenna, as shown in Figure RS103-4, on a dielectric stand at the position and height above the ground plane where the center of the EUT will be located.

e. EUT testing.

(1) Placement of transmit antennas. Antennas shall be placed 1 meter from the test setup boundary as follows:

(a) 10 kHz to 200 MHz

1 Test setup boundaries \leq (less than or equal to) 3 meters. Center the antenna between the edges of the test setup boundary. The boundary includes all enclosures of the EUT and the 2 meters of exposed interconnecting and power leads required by the general section of this standard. Interconnecting leads shorter than 2 meters are acceptable when they represent the actual platform installation.

2 Test setup boundaries $>$ (greater than) 3 meters. Use multiple antenna positions (N) at spacings as shown in Figure RS103-3. The number of antenna positions (N) shall be determined by dividing the edge-to-edge boundary distance (in meters) by 3 and rounding up to an integer.

(b) 200 MHz and above. Multiple antenna positions may be required as shown in Figure RS103-2. Determine the number of antenna positions (N) as follows:

- 1 For testing from 200 MHz up to 1 GHz, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.
- 2 For testing at 1 GHz and above, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

(2) Maintain the placement of electric field sensors as specified in 3e(1) above.

4. Test Procedures. The test procedures shall be as follows:

- a. Turn on the measurement equipment and EUT and allow a sufficient time for stabilization.
- b. Assess the test area for potential RF hazards and take necessary precautionary steps to assure safety of test personnel.
- c. Calibration.
 - (1) Electric field sensor method. Record the amplitude shown on the electric field sensor display unit due to EUT ambient. Reposition the sensor, as necessary, until this level is < 10% of the applicable field strength to be used for testing.
 - (2) Receive antenna method (> 1 GHz).
 - (a) Connect a signal generator to the coaxial cable at the receive antenna connection point (antenna removed). Set the signal source to an output level of 0 dBm at the highest frequency to be used in the present test setup. Tune the measurement receiver to the frequency of the signal source.
 - (b) Verify that the output indication is within ± 3 dB of the applied signal, considering all appropriate losses. If larger deviations are

found, locate the source of the error and correct the deficiency before proceeding.

- (c) Connect the receive antenna to the coaxial cable as shown in Figure RS103-4. Set the signal source to 1 kHz pulse modulation, 50% duty cycle. Using an appropriate transmit antenna and amplifier, establish an electric field at the test start frequency. Gradually increase the electric field level until it reaches the applicable limit.
- (d) Scan the test frequency range and record the required input power levels to the transmit antenna to maintain the required field.
- (e) Repeat procedures (a) through (d) whenever the test setup is modified or an antenna is changed.

d. EUT Testing.

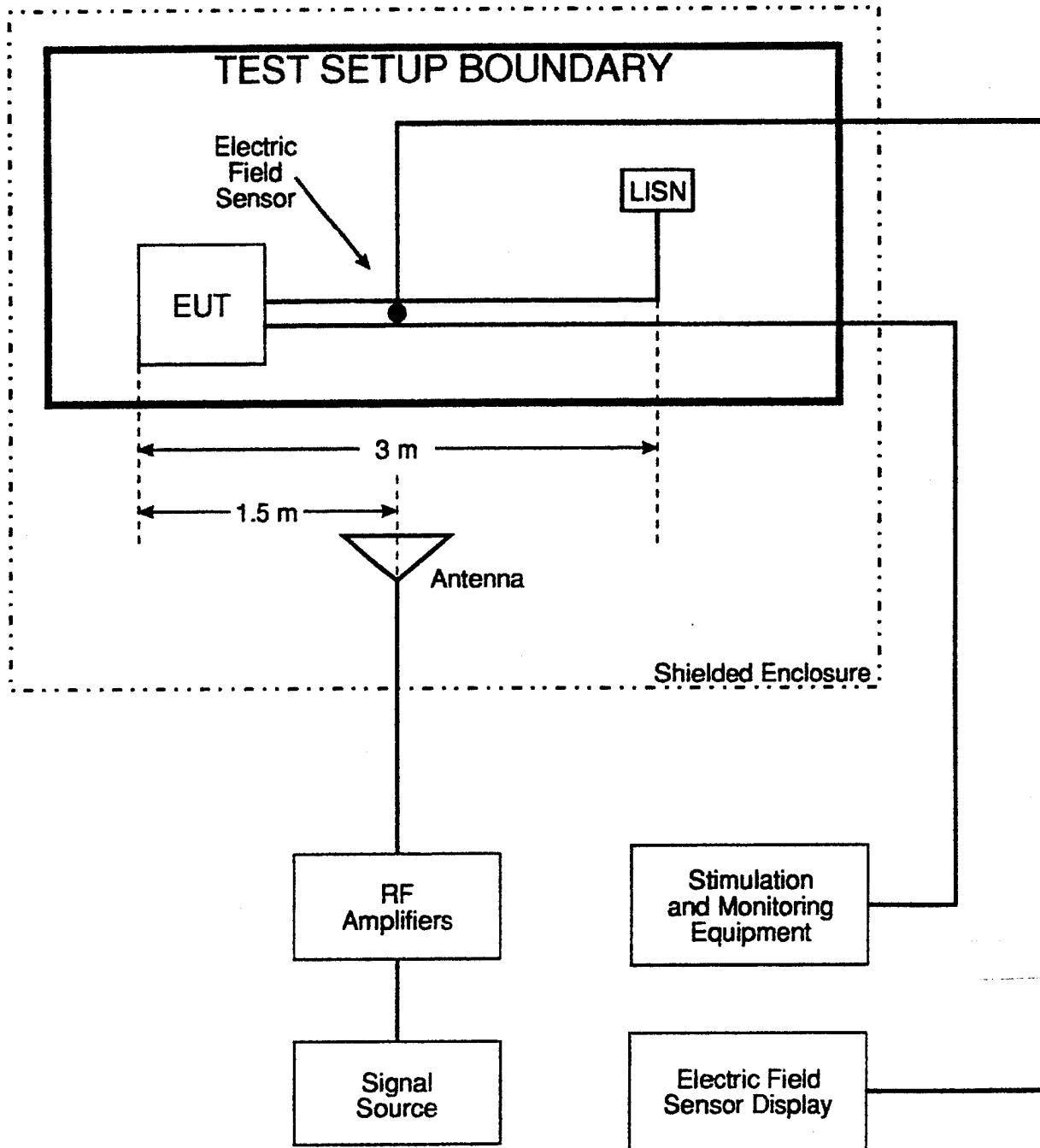
- (1) E-Field sensor method.
 - (a) Set the signal source to 1 kHz pulse modulation, 50% duty cycle, and using appropriate amplifier and transmit antenna, establish an electric field at the test start frequency. Gradually increase the electric field level until it reaches the applicable limit shown in MIL-STD-461.
 - (b) Scan the required frequency ranges in accordance with the rates and durations specified in the general section of this standard. Maintain field strength levels in accordance with the applicable limit. Monitor EUT performance for susceptibility effects.
- (2) Receive antenna method.
 - (a) Remove the receive antenna and reposition the EUT in conformance with 3a.
 - (b) Set the signal source to 1 kHz pulse modulation, 50% duty cycle. Using an appropriate amplifier and transmit antenna, establish an electric field at the test start frequency. Gradually increase the input power level until it corresponds to the

applicable level recorded during the calibration routine.

- (c) Scan the required frequency range in accordance with the rates and durations specified in the general section of this standard while assuring the correct transmitter input power is adjusted in accordance with the calibration data collected. Constantly monitor the EUT for susceptibility conditions.
- (3) If susceptibility is noted, determine the level at which the undesirable response is no longer present and verify it is above the MIL-STD-461 requirement.
- (4) Perform testing over the required frequency range with the transmit antenna vertically polarized. Repeat the testing above 30 MHz with the transmit antenna horizontally polarized.
- (5) Repeat 4d for each transmit antenna position required by 3e.

5. Data Presentation. Data presentation shall be as follows:

- a. Provide graphical or tabular data showing frequency ranges and field strength levels tested.
- b. Provide graphical or tabular data listing (antenna method only) all calibration data collected to include input power requirements used versus frequency, and results of system check in 4c(2)(c) and 4c(2)(d).
- c. Provide the correction factors necessary to adjust sensor output readings for equivalent peak detection of modulated waveforms.
- d. Provide graphs or tables listing any susceptibility thresholds which were determined along with their associated frequencies.
- e. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

FIGURE RS103-1. Test equipment configuration.

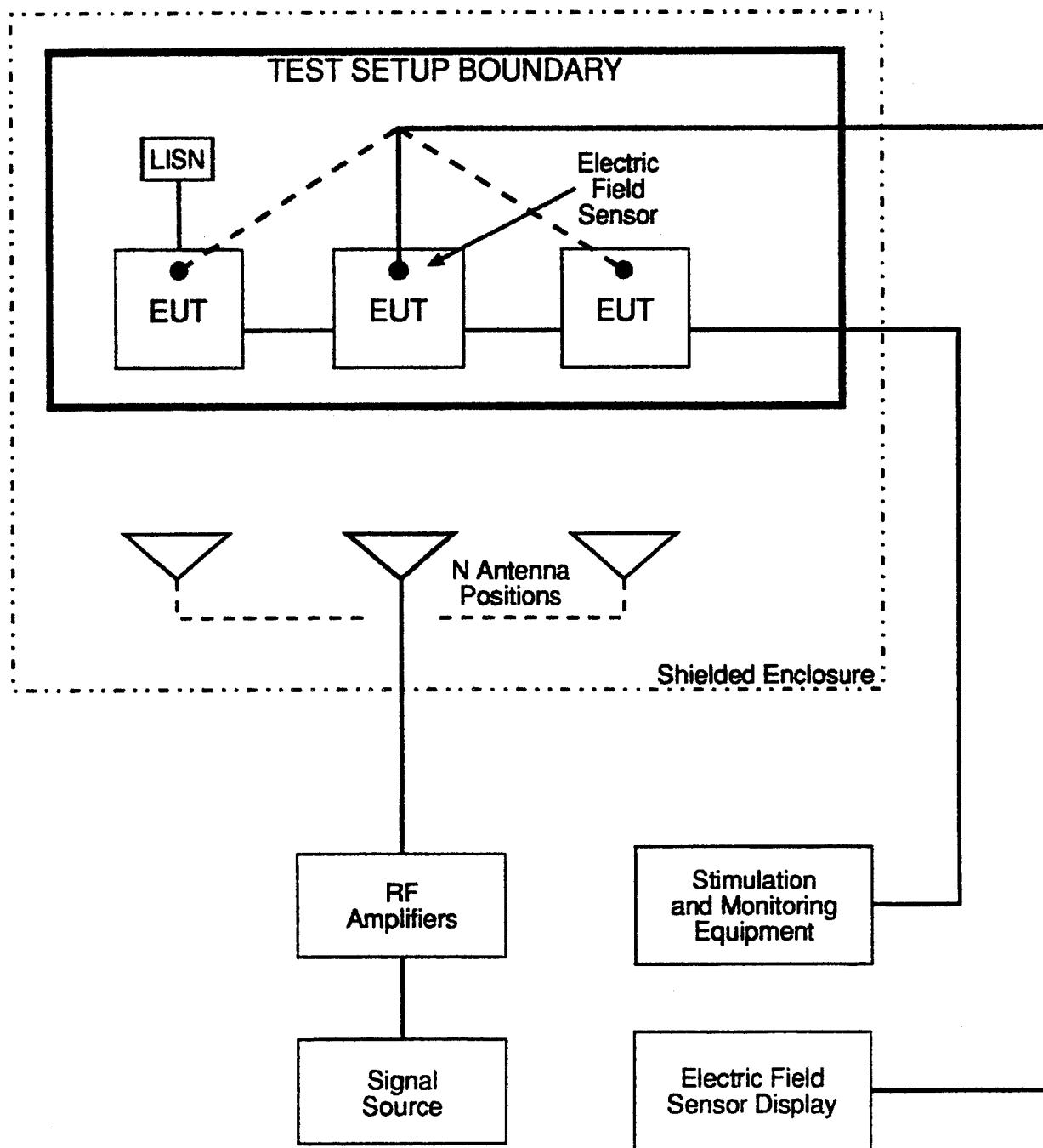


FIGURE RS103-2. Multiple test antenna locations for frequency > 200 MHz.

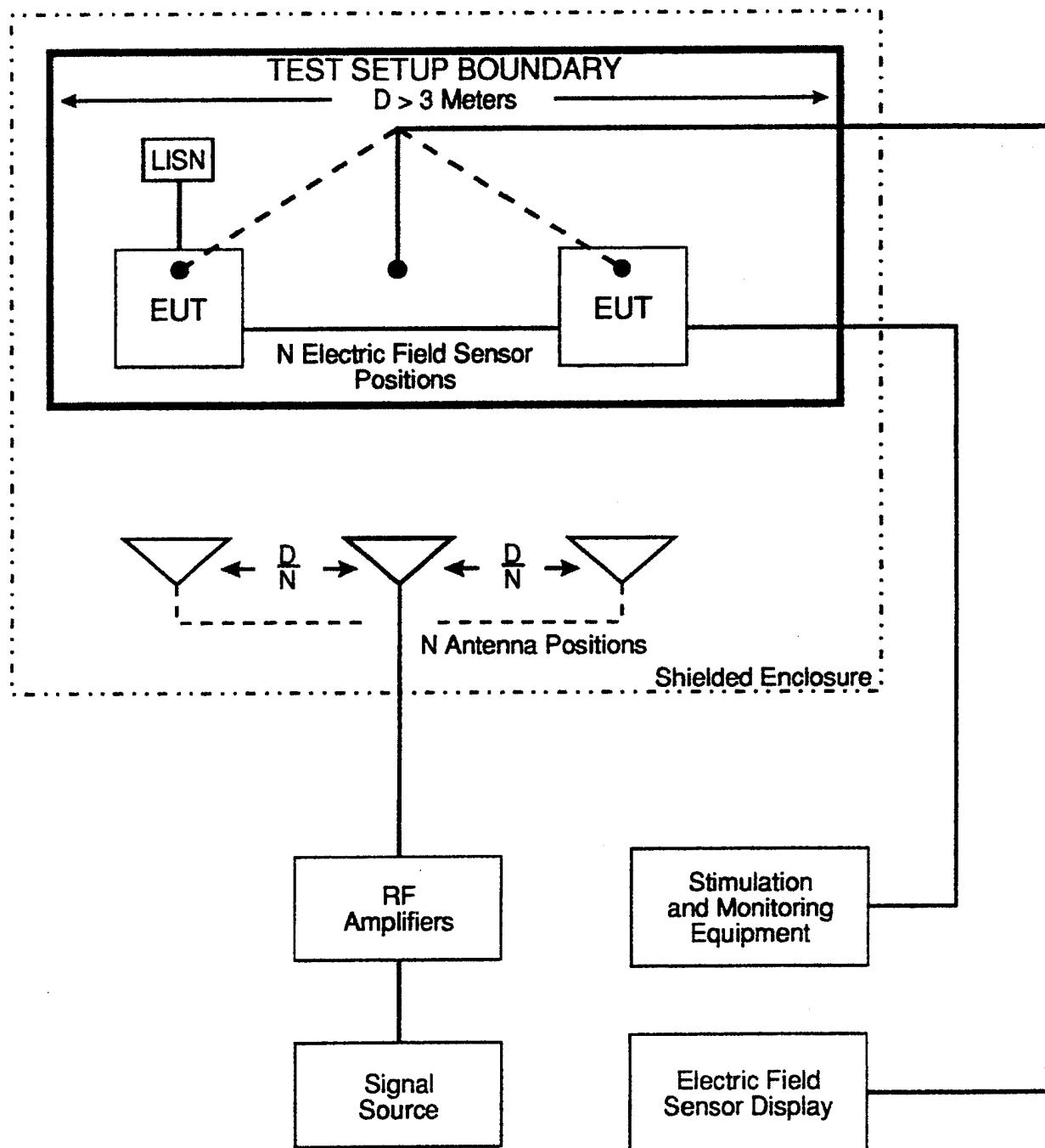
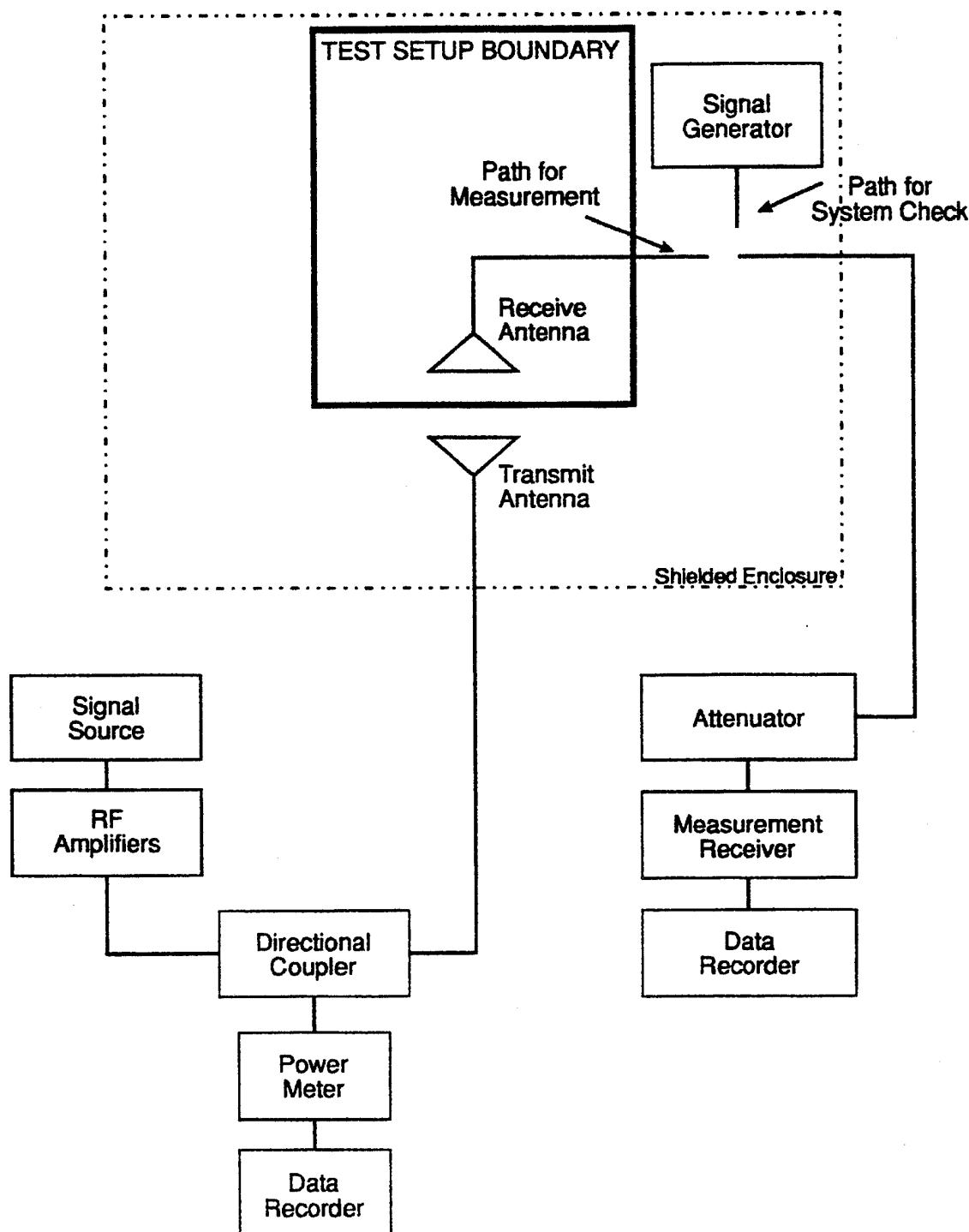


FIGURE RS103-3. Multiple test antenna locations for N positions, $D > 3$ meters.

FIGURE RS103-4. Receive antenna method (1 to 40 GHz).

METHOD RS105

RADIATED SUSCEPTIBILITY, TRANSIENT ELECTROMAGNETIC FIELD

1. Purpose. This test method is used to verify the ability of the EUT enclosure to withstand a transient electromagnetic field.

2. Test Equipment. The test equipment shall be as follows:

- a. Parallel plates, Transverse Electromagnetic (TEM) cell or equivalent
- b. Transient monopulse generator
- c. Storage oscilloscope, 200 MHz minimum single shot bandwidth and a variable sampling rate up to 1 gigasample per second (GSa/s)
- d. Terminal Protection Devices (TPDs)
- e. High-voltage probe
- f. B-Dot sensor and integrator
- g. D-Dot sensor and integrator
- h. LISNs

3. Test Setup. Maintain the basic test setup for the EUT as described below. CAUTION: Exercise extreme care if an open radiator is used for this test.

- a. Calibration. Configure the test equipment in accordance with Figure RS105-1.
 - (1) Place the B-Dot or D-Dot probe with integrator in the middle of the empty radiation system. Connect the probe to a storage oscilloscope.
 - (2) Place the high voltage probe across the radiation system termination load. Connect the probe to a storage oscilloscope.
- b. EUT Testing. Configure the test equipment as shown in Figure RS105-2 for testing of the EUT.

- (1) Place the EUT enclosure on the bottom plate or ground plane of the radiation system in a manner such that it does not exceed the usable volume of the radiation system as shown in Figure RS105-2. The separation between radiating surfaces shall be at least three times the height of the EUT.
- (2) Bond the bottom plate of the radiation system to an earth reference.
- (3) Keep the top plate of the radiation system at least 2 times h from the closest metallic ground, where h is the maximum vertical separation of the plates, including ceiling, building structural beams, metallic air ducts, shielded room walls, and so forth.
- (4) Place the test instrumentation in a shielded enclosure when an open radiator is used.
- (5) Use shielding to protect the cables.
- (6) Place TPDs in the EUT power lines near the power source to protect the power source.
- (7) Connect the monopulse transient generator to the radiation system.

4. Test Procedures. The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow a sufficient time for stabilization.
- b. Calibration. Perform the following procedures using the calibration setup.
 - (1) Generate a single pulse. CAUTION: High voltages are used which are potentially lethal.
 - (2) Observe the pulse to assure that rise time, peak amplitude and decay criteria as specified are met.
- c. EUT Testing. Test the EUT in its orthogonal orientations whenever possible.
 - (1) Turn on the EUT and allow a sufficient time for stabilization.

- (2) Apply the pulse starting at 50% of the required peak level with the specified waveshape. Increase the pulse amplitude slowly until the required level is reached.
- (3) Apply the required number of pulses at a rate of not more than 1 pulse per minute.
- (4) Monitor the applied pulse using at least one of the calibration probes and storage oscilloscope.
- (5) Monitor the EUT during and after the application of each pulse for signs of susceptibility or degradation of performance.
- (6) If an EUT malfunction occurs at a level less than the specified peak level, terminate the test and record the level.
- (7) If susceptibility is noted, determine the level at which the undesirable response is no longer present and verify that it is above the MIL-STD-461 requirement.

5. Data Presentation. Data presentation shall be as follows:

- a. Provide photographs of EUT orientation including cables.
- b. Provide detailed written description of the EUT configuration.
- c. Provide representative oscilloscope photographs of transient waveshape, including peak value, rise and decay times linearly recorded for each applied test transient. Analog time domain X-Y recordings taken from an analog or digitizing oscilloscope are also acceptable.
- d. Provide the pulse number, with the first pulse being Number 1, for each recorded waveshape.
- e. Record the time-to-recovery for each EUT failure, if applicable.

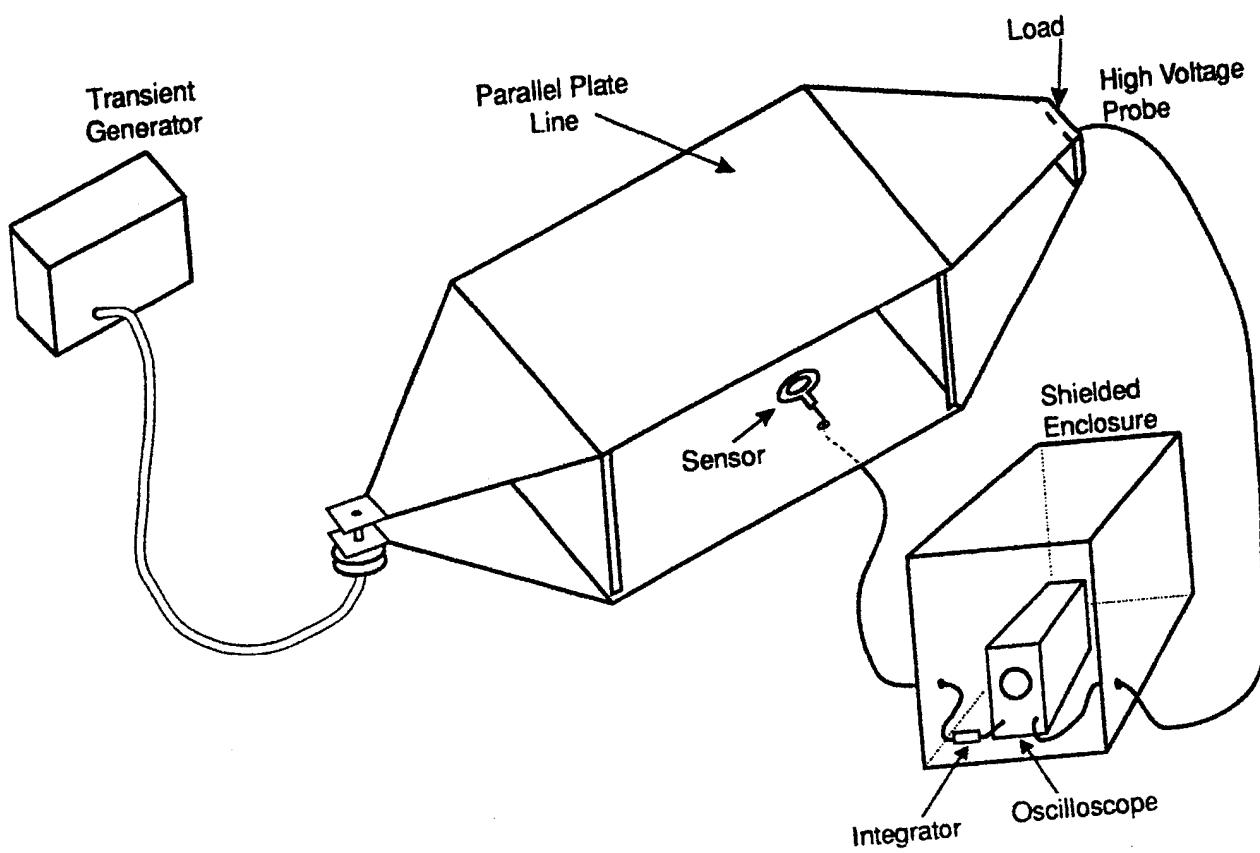


FIGURE RS105-1. Typical calibration setup using parallel plate radiation system.

TOP VIEW

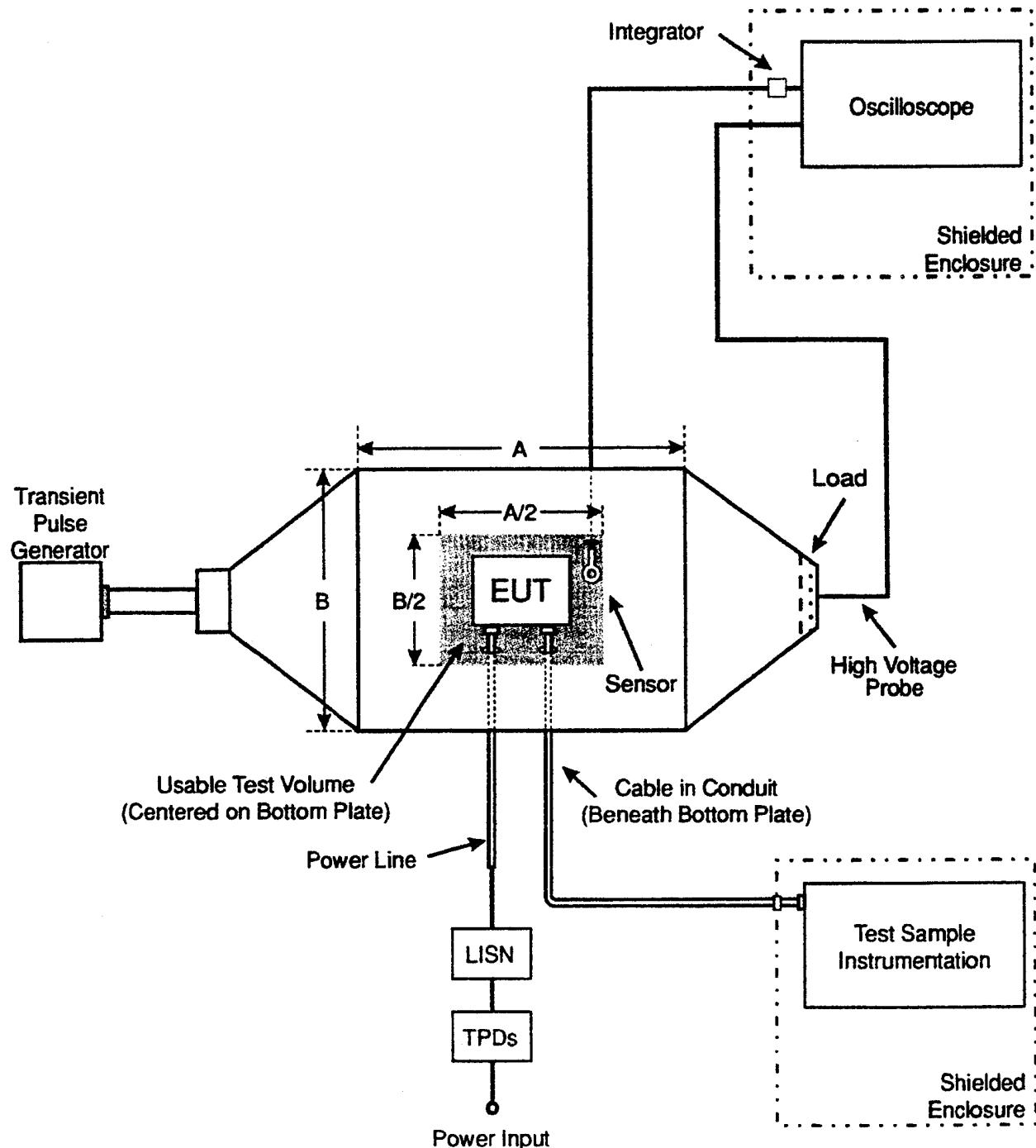


FIGURE RS105-2. Typical test setup using parallel plate radiation system.

CONCLUDING MATERIAL

Custodians:

Army - CR
Navy - EC

Preparing Activity:
Air Force - 11
(Project EMCS-0134)

Review Activities:

Army - MI, AV, TE
Navy - SH, AS, OS, YD, MC, CG, TD
Air Force - 13, 15, 17, 19, 99
NSA

User Activities:

Air Force - 84
Army - AT, ME, CE, CL, MD
DISA
DODECAC
DNA

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**MIL-STD-462D
APPLICATION GUIDE**

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10. GENERAL

10.1 Scope. This appendix provides background information for each requirement in the main body of the standard. The information includes rationale for the test requirements and guidance for application of the requirements. This information should help users understand the intent behind the test requirements and adapt them in the Electromagnetic Interference Test Procedures (EMITP) as necessary for particular applications. This appendix is provided for guidance purposes and, as such, should not be interpreted as providing contractual requirements.

10.2 Structure. This appendix follows the same general format as the main body of the standard. A "DISCUSSION" paragraph is provided for each requirement contained in the standard.

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20. APPLICABLE DOCUMENTS

20.1 Government documents.

20.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

STANDARDS

MILITARY

- | | |
|---------------|---|
| MIL-STD-220 | - Method of Insertion Loss Measurement |
| MIL-STD-285 | - Attenuation Measurements for Enclosures, Electromagnetic Shielding, for Electronic Test Purposes, Method of |
| MIL-STD-461 | - Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility |
| MIL-STD-45662 | - Calibration Systems Requirements |

(Copies of federal and military specifications, standards, and handbooks are available from the Director, Navy Publications and Printing Service Office, 700 Robbins Avenue, Philadelphia, PA 19111-5093.)

20.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

- | | |
|--------|---|
| DODISS | - Department of Defense Index of Specifications and Standards |
|--------|---|

(Copies of the DODISS are available on a yearly subscription basis either from the Government Printing Office for hard copy, or microfiche copies are available from the Director, Navy Publications and Printing Service Office, 700 Robbins Avenue, Philadelphia, PA 19111-5093.)

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20.2. Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DoDISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

- ASTM E 380 - Standard for Metric Practice.
(DOD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

- ANSI/IEEE 268 - Metric Practice. (DOD adopted)
- ANSI C63.2 - Standard for Instrumentation - Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz - Specifications
- ANSI C63.4 - Standard for Electromagnetic Compatibility - Radio-Noise Emissions from Low Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 1 GHz - Methods of Measurement
- ANSI C63.14 - Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD)
- ANSI C95.1 - Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields (300 kHz to 100 GHz)

(Application for copies should be addressed to the IEEE Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

National Electrical Code

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(Application for copies of should be addressed to the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269-9990.)

RADIO TECHNICAL COMMISSION FOR AERONAUTICS

DO-160

- Environmental Conditions and Test Conditions for Airborne Equipment

(Application for copies should be addressed to Radio Technical Commission for Aeronautics Secretariat, One McPherson Square, Suite 500, 1425 K Street, NW, Washington DC 20005.)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

ARP 958

- Electromagnetic Interference Measurement Antennas; Standard Calibration Requirements and Methods

ARP 1972

- Recommended Measurement Practices and Procedures for EMC Testing

(Application for copies should be addressed to the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.)

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30. DEFINITIONS

30.1 General. The terms used in this appendix are defined in ANSI C63.14. In addition, the following definitions are applicable for the purposes of this appendix.

30.2 Acronyms used in this appendix.

- a. BIT - Built-in-Test
- b. CW - Continuous Wave
- c. EMI - Electromagnetic Interference
- d. EMITP - Electromagnetic Interference Test Procedures
- e. EMITR - Electromagnetic Interference Test Report
- f. EMP - Electromagnetic Pulse
- g. ERP - Effective Radiated Power
- h. EUT - Equipment Under Test
- i. GPI - Ground Plane Interference
- j. LISN - Line Impedance Stabilization Network
- k. RF - Radio Frequency
- l. RMS - Root Mean Square
- m. TEM - Transverse Electromagnetic
- n. VSWR - Voltage Standing Wave Ratio

30.3 Metric units. Metric units are a system of basic measures which are defined by the International System of Units based on "Le System International d'Unites (SI)", of the International Bureau of Weights and Measures. These units are described in ASTM E 380 and ANSI/IEEE 268.

30.4 Test setup boundary. The test setup boundary includes all enclosures of the Equipment Under Test (EUT) and the 2 meters of exposed interconnecting leads (except for leads which are shorter in the actual installation) and power leads required by the general section of this standard.

40. REQUIREMENTS

40.1 (4.1) General. General requirements related to test methods, test facilities, and equipment are as stated below. Any approved exceptions or deviations from these general test requirements shall be documented in the EMITP required by MIL-STD-461.

DISCUSSION: This portion of the document specifies requirements that are applicable to a variety of test methods. Individual test methods include requirements which are unique to that test method only. Other sources of information dealing with electromagnetic interference testing are available in industry documents such as RTCA DO-160 and SAE ARP 1972.

40.1.1 (4.1.1) Measurement tolerances. Unless otherwise stated for a particular measurement, the tolerance shall be as follows:

- a. Distance: $\pm 5\%$
- b. Frequency: $\pm 2\%$
- c. Amplitude, measurement receiver: ± 2 dB
- d. Amplitude, measurement system (includes measurement receivers, transducers, cables, and so forth): ± 3 dB
- e. Time (waveforms): $\pm 5\%$

DISCUSSION: Tolerances are necessary to maintain reasonable controls for obtaining consistent measurements. Paragraphs 4.1.4.b through 4.1.4.d are in agreement with ANSI C63.2 for electromagnetic noise instrumentation.

40.2 (4.2) Shielded enclosures. To prevent interaction between the Equipment Under Test (EUT) and the outside environment, shielded enclosures will usually be required for testing. These enclosures prevent external environment signals from contaminating emission measurements and susceptibility test signals from interfering with electrical and electronic items in the vicinity of the test facility. Shielded enclosures must have adequate attenuation such that the ambient requirements of paragraph 4.4 are satisfied. The enclosures must be sufficiently large such that the EUT arrangement requirements of paragraph 4.8 and antenna positioning requirements described in the individual test methods are satisfied.

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DISCUSSION: Potential accuracy problems introduced by shielded enclosure resonances are well documented and recognized; however, shielded enclosures are usually a necessity for testing of military equipment to MIL-STD-461 requirements. Most test agencies are at locations where ambient levels outside of the enclosures are significantly above MIL-STD-461 limits and would interfere with the ability to obtain meaningful data.

Electrical interfaces with military equipment are often complex and require sophisticated test equipment to simulate and evaluate the interface. This equipment usually must be located outside of the shielded enclosure to achieve sufficient isolation and prevent it from contaminating the ambient and responding to susceptibility signals.

The shielded enclosure also prevents radiation of applied susceptibility signals from interfering with local antenna-connected receivers. The most obvious potential offender is the RS103 test. However, other susceptibility tests can result in substantial radiated energy which may violate Federal Communication Commission (FCC) rules. Shielded enclosures with the following characteristics will typically provide the required isolation:

- a. Shielding effectiveness of 80 decibels (dB) with respect to electric fields and plane waves above 10 kHz as measured in accordance with MIL-STD-285.
- b. Powerline filtering of 80 dB attenuation at frequencies above 10 kHz as measured in accordance with MIL-STD-220.

40.2.1 (4.2.1) Radio Frequency (RF) absorber material. RF absorber material (carbon impregnated foam pyramids, ferrite tiles, and so forth) shall be used when performing electric field radiated emission or radiated susceptibility testing inside a shielded enclosure to reduce reflections of electromagnetic energy and to improve accuracy and repeatability. The RF absorber shall be placed above, behind, and on both sides of the EUT, and behind the radiating or receiving antenna as shown in Figure 1. Minimum performance of the material shall be as specified in Table I. The manufacturer's certification of their RF absorber material (basic material only, not installed) is acceptable.

DISCUSSION: Accuracy problems with making measurements in untreated shielded enclosures due to reflections of electromagnetic energy have been widely recognized and documented. The values of RF absorption required by Table I are considered to be sufficient to substantially improve the integrity of the measurements without unduly impacting test

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facilities. The minimum placement provisions for the material are specified to handle the predominant reflections. The use of additional material is desirable, where possible. It is intended that the values in Table I can be met with available ferrite tile material or standard 24 inch (0.61 meters) pyramidal absorber material.

TABLE I. Absorption at Normal Incidence.

Frequency	Minimum Absorption
80 MHz - 250 MHz	6 dB
above 250 MHz	10 dB

40.3 (4.3) Other test sites. If other test sites are used, the ambient requirements of paragraph 4.4 shall be met.

DISCUSSION: For certain types of EUTs, testing in a shielded enclosure may not be practical. Examples are EUTs which are extremely large, require high electrical power levels or motor drives to function, emit toxic fumes, contain explosives such as squibs, or are too heavy for normal floor loading. There is a serious concern with ambient levels contaminating data when testing is performed outside of a shielded enclosure. Therefore, special attention is given to this testing under paragraph 4.4, "Ambient electromagnetic level." All cases where testing is performed outside a shielded enclosure shall be justified in detail in the EMITP including typical profiles of expected ambient levels.

An option in emission testing is the use of an open area test site (OATS) in accordance with ANSI C63.4. These sites are specifically designed to enhance accuracy and repeatability. Due to differences between ANSI C63.4 and this standard in areas such as antenna selection, measurement distances, and specified frequency ranges, the EMITP shall detail the techniques for using the OATS and relating the test results to MIL-STD-461 requirements.

40.4 (4.4) Ambient electromagnetic level. During testing, the ambient electromagnetic level measured with the EUT de-energized and all auxiliary equipment turned on shall be at least 6 dB below the allowable specified limits when the tests are performed in a shielded enclosure. Ambient conducted levels on power leads shall be measured with the leads disconnected from the EUT and connected to a resistive load which draws the same rated current as the EUT. When tests are performed in a shielded enclosure and the EUT is in compliance with MIL-STD-461 limits, the ambient profile need not be recorded in the Electromagnetic

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Interference Test Report (EMITR). When measurements are made outside a shielded enclosure, the tests shall be performed during times and conditions when the ambient is at its lowest level. The ambient shall be recorded in the EMITR required by MIL-STD-461 and shall not compromise the test results.

DISCUSSION: Controlling ambient levels is critical to maintaining the integrity of the gathered data. High ambients present difficulties distinguishing between EUT emissions and ambient levels. Even when specific signals are known to be ambient related, they may mask EUT emissions which are above MIL-STD-461 limits.

The requirement that the ambient be at least 6 dB below the limit ensures that the combination of the EUT emissions and ambient does not unduly affect the indicated magnitude of the emission. Since the EUT emissions are not phase coherent with the ambient, the signals combine with the square root of the sum of the squares of the individual voltage amplitudes. If a true emission level is at the limit and the ambient is 6 dB below the limit, the indicated level would be 1.0 dB above the limit. Similarly, if the ambient were allowed to be equal to the limit for the same true emission level, the indicated level would be 3.0 dB above the limit.

A resistive load is specified to be used for conducted ambients on power leads. However, under certain conditions actual ambient levels may be higher than indicated with a resistive load. The most likely reason is the presence of capacitance at the power interface of the EUT which will lower the input impedance at higher frequencies and increase the current. This capacitance should be determined and ambient measurements repeated with the capacitance in place. There is also the possibility of resonance conditions with shielded room filtering, EUT filtering, and powerline inductance. These types of conditions may need to be investigated if unexpected emission levels are observed.

Testing outside of a shielded enclosure often must be performed at night to minimize influences of the ambient. A prevalent problem with the ambient is that it continuously changes with time as various emitters are turned on and off and as amplitudes fluctuate. A useful tool for improving the flow of testing is to thoroughly analyze the EUT circuitry prior to testing and identify frequencies where emissions may be expected to be present.

An option to improve overall measurement accuracy is to make preliminary measurements inside a shielded enclosure and accurately determine frequencies where emissions are present. Testing can be continued outside the shielded enclosure with

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measurements being repeated at the selected frequencies. The 6 dB margin between the ambient and limits must then be observed only at the selected frequencies.

40.5 (4.5) Ground plane. The EUT shall be installed on a ground plane that simulates the actual installation. If the actual installation is unknown or multiple installations are expected, then a metallic ground plane shall be used. Unless otherwise specified below, ground planes shall be 2.25 square meters or larger in area with the smaller side no less than 76 centimeters. When a ground plane is not present in the EUT installation, the EUT shall be placed on a non-conductive surface.

DISCUSSION: Generally, the radiated emissions and radiated susceptibilities of equipment are due to coupling from and to the interconnecting cables and not via the case of the EUT. Emissions and susceptibility levels are directly related to the placement of the cable with respect to the ground plane and to the electrical conductivity of the ground plane. Thus, the ground plane plays an important role in obtaining the most realistic test results.

When the EUT is too large to be installed on a conventional ground plane on a bench, the actual installation should be duplicated. For example, a large radar antenna may need to be installed on a test stand and the test stand bonded to the floor of the shielded enclosure. Ground planes need to be placed on the floor of shielded rooms with floor surfaces such as tiles which are not electrically conductive.

The use of ground planes is also applicable for testing outside of a shielded enclosure. These ground planes will need to be referenced to earth as necessary to meet the electrical safety requirements of the National Electrical Code. Where possible, these ground planes should be electrically bonded to other accessible grounded reference surfaces such as the outside structure of a shielded enclosure.

The minimum dimensions for a ground plane of 2.25 square meter with 76 centimeters on the smallest side will be adequate only for setups involving a limited number of EUT enclosures with few electrical interfaces. The ground plane must be large enough to allow for the requirements included in paragraph 4.8 on positioning and arrangement of the EUT and associated cables to be met.

40.5.1 (4.5.1) Metallic ground plane. When the EUT is installed on a metallic ground plane, the ground plane shall have a surface resistance no greater than 0.1 milliohms per square. The DC resistance between metallic ground planes and the shielded

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enclosure shall be 2.5 milliohms or less. The metallic ground planes shown in Figures 2 through 5 shall be electrically bonded to the floor or wall of the basic shielded room structure at least once every 1 meter. The metallic bond straps shall be solid and maintain a five-to-one ratio or less in length to width. Metallic ground planes used outside a shielded enclosure shall be at least 2 meters by 2 meters and extend at least 0.5 meter beyond the test setup boundary.

DISCUSSION: For the metallic ground plane, a copper ground plane with a thickness of 0.25 millimeters has been commonly used and satisfies the surface resistance requirements. Other metallic materials of the proper size and thickness needed to achieve the resistivity can be substituted.

For metallic ground planes, the surface resistance can be calculated by dividing the bulk resistivity by the thickness. For example, copper has a bulk resistivity of $1.75(10^{-8})$ ohm-meters. For a 0.25 millimeter $2.5(10^{-4})$ meters) thick ground plane as noted above, the surface resistance is $(1.7(10^{-8}))/(2.5(10^{-4})) = (6.8(10^{-5}))$ ohms per square = 0.068 milliohms per square. The requirement is 0.1 milliohms per square.

40.5.2 (4.5.2) Composite ground plane. When the EUT is installed on a conductive composite ground plane, the surface resistivity of the typical installation shall be used. Composite ground planes shall be electrically bonded to the enclosure with means suitable to the material.

DISCUSSION: A copper ground plane has typically been used for all testing in the past. For most instances, this has been adequate. However, with the increasing use of composites, the appropriate ground plane will play a bigger role in the test results. Limited testing on both copper and conductive composite ground planes has shown some differences in electromagnetic coupling test results, thus the need exists to duplicate the actual installation, if possible. In some cases, it may be necessary to include several ground planes in the same test setup if different units of the same EUT are installed on different materials in the installation.

With the numerous different composite materials being used in installations, it is not possible to specify a general resistivity value. The typical resistivity of carbon composite is about 2000 times that of aluminum. The actual resistivity needs to be obtained from the installation contractor and used for testing.

40.6 (4.6) Power source impedance. The impedance of power sources providing input power to the EUT shall be controlled by

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Line Impedance Stabilization Networks (LISNs) for all measurements procedures of this document unless otherwise stated in a particular test method. The LISNs shall be located at the power source end of the exposed length of power leads specified in paragraph 4.8.5.2. The LISN circuit shall be in accordance with the schematic shown in Figure 6. The LISN impedance characteristics shall be in accordance with Figure 7. The LISN impedance shall be measured under the following conditions:

- a. The impedance shall be measured between the power output lead on the load side of the LISN and the metal enclosure of the LISN.
- b. The signal output port of the LISN shall be terminated in fifty ohms.
- c. The power input terminal on the power source side of the LISN shall be unterminated.

The impedance measurement results shall be provided in the EMITR required by MIL-STD-461

DISCUSSION: The impedance is standardized to represent expected impedances in actual installations and to ensure consistent results between different test agencies. Previous versions of MIL-STD-462 used 10 microfarad feedthrough capacitors on the power leads. The intent of these devices was to determine the current generator portion of a Norton current source model. If the impedance of the interference source were also known, the interference potential of the source could be analytically determined for particular circumstances in the installation. A requirement was never established for measuring the impedance portion of the source model. More importantly, concerns arose over the test configuration influencing the design of powerline filtering. Optimized filters are designed based on knowledge of both source and load impedances. Significantly different filter designs will result for the 10 microfarad capacitor loading versus the impedance loading shown in Figure 7 of the main body.

The particular configuration of the LISN is specified for several reasons. A number of experiments were performed to evaluate typical power line impedances present in a shielded room on various power input types both with and without power line filters and to assess the possible methods of controlling the impedance. An approach was considered for the standard to simply specify an impedance curve from 30 Hz to 100 MHz and to allow the test agency to meet the impedance using whatever means the agency found suitable. The experiments showed that there were no straightforward techniques to maintain desired controls over the entire frequency range.

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A specific 50 microhenry LISN was selected to maintain a standardized control on the impedance as low as 10 kHz. Five microhenry LISNs used commonly in the past provide little control below 100 kHz. Impedance control below 10 kHz is difficult. From evaluations of several 50 microhenry LISN configurations, the one specified demonstrated the best overall performance for various shielded room filtering variations. Near 10 kHz, the reactances of the 50 microhenry inductor and 8 microfarad capacitor cancel and the LISN is effectively a 5 ohm resistive load across the power line.

Caution needs to be exercised in using the LISN for 400 Hz power systems. Some existing LISNs may not have components sufficient to handle the power dissipation requirements. At 115 volts, 400 Hz, the 8 microfarad capacitor and 5 ohm resistor will pass approximately 2.3 amperes which results in 26.5 watts being dissipated in the resistor.

40.7 (4.7) General test precautions.

DISCUSSION: The requirements included in paragraph 4.7 cover important areas related to improving test integrity and safety that need special attention. There are many other areas where test difficulties may develop. Some are described here.

It is common for shields to become loose or broken at connectors on coaxial cables resulting in incorrect readings. There also are cases where center conductors of coaxial cables break or separate. Periodic tests should be performed to ensure cable integrity. Special low loss cables may be required when testing at higher frequencies.

Caution needs to be exercised when performing emission testing at frequencies below approximately 10 kHz to avoid ground loops in the instrumentation which may introduce faulty readings. A single-point ground often needs to be maintained. It is usually necessary to use isolation transformers at the measurement receiver and accessory equipment. The single-point ground is normally established at the access (feedthrough) panel for the shielded enclosure. However, if a transducer is being used which requires an electrical bond to the enclosure (such as the rod antenna counterpoise), the coaxial cable will need to be routed through the enclosure access panel without being grounded. Since the shielded room integrity will then be compromised, a normal multiple point grounded setup needs to be re-established as low in frequency as possible.

Rather than routing the coaxial cable through the enclosure access panel without grounding it to the enclosure, a 50-ohm video isolation transformer may be connected to the grounded RF connector at the access panel inside the room. Normal connection

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of the measuring receiver is made to the grounded connector at the panel outside the room. This technique effectively breaks the ground loop without sacrificing the room's shielding integrity. The losses of the video isolation transformer must be accounted for in the measurement data. These devices are typically useful up to approximately 10 MHz.

If isolation transformers are found to be necessary in certain setups, problems may exist with items powered by switching power supplies. A solution is to use transformers which are rated at approximately five times the current rating of the item.

Solid state instrumentation power sources have been found to be susceptible to radiated fields even to the extent of being shut down. It is best to keep these items outside of the shielded enclosure.

40.7.1 (4.7.1) Accessory equipment. Accessory equipment used in conjunction with measurement receivers shall not degrade measurement integrity.

DISCUSSION: Measurement receivers are generally designed to meet MIL-STD-461 limits so they do not contaminate the ambient for emission testing when they are used inside the shielded enclosure. However, accessory equipment such as computers, oscilloscopes, plotters, or other instruments used to control the receiver or monitor its outputs can cause problems. They may compromise the integrity of the receiver by radiating signals conducted out of the receiver from improperly treated electrical interfaces or may produce interference themselves and raise the ambient. Even passive devices such as headsets have been known to impact the test results.

It is best to locate all of the test equipment outside of the shielded enclosure with the obvious exception of the transducer (antenna or current probe). Proper equipment location will ensure that the emissions being measured are being generated in the EUT only and will help ensure that the ambient requirements of paragraph 4.4 are met. If the equipment must be used inside the enclosure or if testing is being conducted outside of an enclosure, the measurement receiver and accessory equipment should be located as far away from the transducers as practical to minimize any impact.

40.7.2 (4.7.2) Excess personnel and equipment. The test area shall be kept free of unnecessary personnel, equipment, cable racks, and desks. Only the equipment essential to the test being performed shall be in the test area or enclosure. Only personnel actively involved in the test shall be permitted in the enclosure.

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DISCUSSION: Excess personnel and both electronic and mechanical equipment such as desks or cable racks in the enclosure can affect the test results. During radiated emission testing in particular, all nonessential personnel and equipment need to be removed from the test site. Any object in the enclosure can significantly influence or introduce standing waves in the enclosure and thus alter the test results. The requirement to use RF absorber material will help to mitigate these effects. However, requirements for the material are not defined below 80 MHz for practical reasons and standing waves continue to be a concern.

40.7.3 (4.7.3) Overload precautions. Measurement receivers and transducers are subject to overload, especially receivers without preselectors and active transducers. Periodic checks shall be performed to assure that an overload condition does not exist. Instrumentation changes shall be implemented to correct any overload condition.

DISCUSSION: Overloads can easily go unnoticed if there is not an awareness of the possibility of an overload or active monitoring for the condition. The usual result is a leveling off of the output indication of the receiver.

Two types of overloads are possible. A narrowband signal such as a sinusoid can saturate any receiver or active transducer. Typical procedures for selecting attenuation settings for measurement receivers place detected voltages corresponding to MIL-STD-461 emission limits well within the dynamic range of the receiver. Saturation problems for narrowband type signals will normally only appear for a properly configured receiver if emissions are significantly above the limits. Saturation can occur more readily when receivers are used to monitor susceptibility signals due to the larger voltages involved.

Overload from impulsive type signals with broad frequency content can be much more deceptive. This condition is most likely to occur with devices without a tuneable bandpass feature in the first stage of the signal input. Examples are preamplified rod antennas and receivers without preselectors (primarily certain spectrum analyzers). The input circuitry is exposed to energy over a large portion of the frequency spectrum. Preselectors include a tuneable tracking filter which bandwidth limits the energy applied to the receiver front end circuitry.

Measurement receiver overload to both narrowband and impulsive type signals can be evaluated by applying 10 dB additional attenuation in the first stage of the receiver (before mixer circuitry) or external to the receiver. If overload is not present, the observed output will uniformly decrease by 10 dB.

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Overload conditions for active antennas are normally published as part of the literature supplied with the antenna. For narrowband signals, the indicated level in the data can be reviewed with respect to the literature to evaluate overload. Levels are also published for impulsive type signals; however, these levels are not very useful since they usually assume that a flat field exists across the useable range of the antenna. In reality, the impulsive field will vary significantly with frequency and the antenna circuitry sees the integration of the spectral content of this field over its bandpass. The primary active antenna used is an active rod antenna. Overload can be evaluated by collapsing the rod and observing the change in indication. If overload is not present, the indicated level should drop approximately 8 dB. The actual change for any particular manufacturer's product will depend on the telescoping design and can be determined by radiating a signal to the antenna which is within its linear range.

40.7.4 (4.7.4) RF hazards. Some tests in this standard will result in electromagnetic fields which are potentially dangerous to personnel. The permissible exposure levels in ANSI C95.1 shall not be exceeded in areas where personnel are present. Safety procedures and devices shall be used to prevent accidental exposure of personnel to RF hazards.

DISCUSSION: During some radiated susceptibility and radiated emission testing, RS103, RS105 and RE103 in particular, fields may exceed the permissible exposure levels in ANSI C95.1. During these tests, precautions must be implemented to avoid inadvertent exposure of personnel. Monitoring of the EUT during testing may require special techniques such as remotely connected displays external to the enclosure or closed circuit television to adequately protect personnel.

40.7.5 (4.7.5) Shock hazard. Some of the tests require potentially hazardous voltages to be present. Extreme caution must be taken by all personnel to assure that all safety precautions are observed.

DISCUSSION: A safety plan and training of test personnel are normally required to assure that accidents are minimized. Test equipment manufacturers' precautions need to be followed, if specified. If these are not available, the test laboratory should establish adequate safety precautions and train all test personnel. Special attention should be observed for Method CS109 since electronics enclosures are intentionally isolated from the ground plane for test purposes.

40.7.6 (4.7.6) Federal Communication Commission (FCC) restrictions. Some of the tests require high level signals to be generated that could interfere with normal FCC approved frequency

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assignments. All such testing should be conducted in a shielded enclosure. Some open site testing may be feasible if prior FCC coordination is obtained.

DISCUSSION: Radiated susceptibility RS103 testing and possibly other tests will produce signals above FCC authorizations. This situation is one of the reasons that shielded enclosures are usually required for MIL-STD-462 testing. In some rare instances, the FCC may permit levels higher than normal if prior coordination is obtained.

40.8 (4.8) EUT test configurations. The EUT shall be configured as shown in the general test setups of Figures 1 through 5 as applicable. These setups shall be maintained during all testing unless other direction is given for a particular test method.

DISCUSSION: Emphasis is placed on "maintaining" the specified setup for all testing unless a particular test method directs otherwise. Confusion has resulted from previous versions of the standard regarding consistency of setups from test method to test method in areas such as lead lengths and placement of 10 uF capacitors on power leads. In this version of the standard, any changes from the general test setup are specifically stated in the individual test method.

40.8.1 (4.8.1) Bonding of EUT. Only the provisions included in the design of the EUT shall be used to bond units such as equipment case and mounting bases together, or to the ground plane. When bonding straps are required to complete the test setup, they shall be identical to those specified in the installation drawings.

DISCUSSION: Electrical bonding provisions for equipment are an important aspect of platform installation design. Adequacy of bonding is usually one of the first areas reviewed when platform problems develop. Electrical bonding controls common mode voltages that develop between the equipment enclosures and the ground plane. Voltages potentially affecting the equipment will appear across the bonding interface when RF stresses are applied during susceptibility testing. Voltages will also develop due to internal circuit operation and will contribute to radiated emission profiles. Therefore, it is important that the test setup use actual bonding provisions so that test results are representative of the intended installation.

40.8.2 (4.8.2) Shock and vibration isolators. EUTs shall be secured to mounting bases having shock or vibration isolators if such mounting bases are used in the installation. The bonding straps furnished with the mounting base shall be connected to the

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ground plane. When mounting bases do not have bonding straps, bonding straps shall not be used in the test setup.

DISCUSSION: Including shock and vibration isolators in the setup when they represent the platform installation is important. The discussion above for paragraph 4.8.1 is also applicable to shock and vibration isolators; however, the potential effect on test results is even greater. Hard mounting of the equipment enclosures to the ground plane can produce a low impedance path across the bonding interface over most of the frequency range of interest. The bonding straps associated with isolators will typically represent significant impedances at frequencies as low as tens of kilohertz. The common mode voltages associated with these impedances will generally be greater than the hard mounted situation. Therefore, the influence on test results can be substantial.

40.8.3 (4.8.3) Wire grounds. When external terminals, connector pins, or equipment grounding conductors in power cables are available for ground connections and are used in the actual installation, they shall be connected to the ground plane after a 2 meter exposed length (see 4.8.5). Shorter lengths shall be used if they are specified in the installation instructions.

DISCUSSION: Wire grounds used in equipment enclosures have been the source of problems during EMI testing. Since they are connected to the equipment enclosure, they would be expected to be at a very low potential with respect to the ground plane and a non-contributor to test results. However, the wire lengths within enclosures are often sufficiently long that coupling to them results from noisy circuits. Also, the wire grounds can conduct induced signals from external sources and reradiate within the equipment enclosure. Therefore, they must be treated similarly to other wiring.

40.8.4 (4.8.4) Orientation of EUTs. EUTs shall be oriented such that surfaces which produce maximum radiated emissions and respond most readily to radiated signals face the measurement antennas. Bench mounted EUTs shall be located 10 \pm 2 centimeters from the front edge of the ground plane subject to allowances for providing adequate room for cable arrangement as specified below.

DISCUSSION: Determination of appropriate surfaces is usually straightforward. Seams on enclosures which have metal-to-metal contact or contain EMI gaskets rarely contribute and should be considered low priority items. Prime candidates are displays such as video screens, ventilation openings, and cable penetrations. In some cases, it may be necessary to probe the surfaces with a sensor and measurement receiver to decide on EUT orientation.

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Previous versions of this standard specifically required probing with a loop antenna to determine localized areas producing maximum emissions or susceptibility for radiated electric field testing. The test antennas were to be placed one meter from the identified areas. The requirement was not included in this version of MIL-STD-462 due to difficulties in applying the requirement and the result that probing was often not performed. Probing implies both scanning in frequency and physical movement of the probe. These two actions cannot be performed in a manner to cover all physical locations at all frequencies. A complete frequency scan can be performed at particular probe locations and movement of the probe over the entire test setup can be performed at particular frequencies. The detailed requirements on the use of multiple antenna positions and specific requirements on the placement of the antennas in test methods RE102 and RS103 minimize concerns with the need to probe.

40.8.5 (4.8.5) Construction and arrangement of EUT cables.
Electrical cable assemblies shall simulate actual installation and usage. Shielded cables or shielded leads (including power lead and wire grounds) within cables shall be used only if they have been specified in installation drawings. Cables shall be checked against installation requirements to verify proper construction techniques such as use of twisted pairs, shielding, and shield terminations. Details on the cable construction used for testing shall be included in the EMITP.

DISCUSSION: For most EUTs, electrical interface requirements are covered in interface control or similar documents. Coordination between equipment manufacturers and system integration organizations is necessary to ensure a compatible installation from both functional and electromagnetic interference standpoints. For general purpose EUTs, which may be used in many different installations, either the equipment specifications cover the interface requirements or the manufacturers publish recommendations in the documentation associated with the equipment.

Equipment manufacturers sometimes contend that failures during EMI testing are not due to their equipment and can be cured simply by placing overall shields on the interface cabling. This concept is unacceptable. High level emissions are often caused by electronic circuits within EUT enclosures coupling onto cables simulating the installation which interface with the EUT. Overall shielding of the cabling is certainly permissible if it is present in the installation. However, the use of overall shielding which is not representative of the installation would result in test data which is useless. Also, overall shielding of cabling in some installations is not a feasible option due to weight and maintenance penalties. The presence of platform

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structure between cabling and antennas on a platform is not an acceptable reason for using overall shields on cables for testing in accordance with this standard. The presence of some platform shielding is a basic assumption.

There may be instances when published interface information is not available. In this case, overall shielding is not to be used. Individual circuits are to be treated as they typically would for that type of interface with shielding not used in questionable cases.

For some testing performed in the past using bulk cable drive techniques, overall cable shields were routinely removed and the injected signal was applied to the core wiring within the shield. The intent of this standard is to test cables as they are configured in the installation. If the cable uses an overall shield, the test signal is applied to the overall shielded cable. If the procuring agency desires that the test be performed on the core wiring, specific wording needs to be included in contractual documentation.

40.8.5.1 (4.8.5.1) Interconnecting leads and cables.
Individual leads shall be grouped into cables in the same manner as in the actual installation. Total interconnecting cable lengths in the setup shall be the same as in the actual platform installation. If the cable is longer than 10 meters, at least 10 meters shall be included. When cable lengths are not specified for the installation, cables shall be sufficiently long to satisfy the conditions specified below. At least 2 meters (except for cables which are shorter in the actual installation) of each interconnecting cable shall be run parallel to the front boundary of the setup. Remaining cable lengths shall be routed to the back of the setup and shall be placed in a zig-zagged arrangement. When the setup includes more than one cable, individual cables shall be separated by 2 centimeters measured from their outer circumference. For bench top setups using ground planes, the cable closest to the front boundary shall be placed 10 centimeters from the front edge of the ground plane. All cables shall be supported 5 centimeters above the ground plane.

DISCUSSION: Actual lengths of cables used in installations are necessary for several reasons. At frequencies below resonance, coupling is generally proportional to cable length. Resonance conditions will be representative of the actual installation. Also, distortion and attenuation of intentional signals due strictly to cable characteristics will be present and potential susceptibility of interface circuits to induced signals will therefore be similar to the actual installation.

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Zig-zagging of long cables is accomplished by first placing a length of cable in an open area and then reversing the direction of the cable run by 180 degrees each time a change of direction is required. Each subsequent segment is farther from the first. Individual segments of the cable are parallel and should be kept 2 centimeters apart. This arrangement is sometimes called a serpentine pattern. The zig-zagging of long cables rather than coiling is to control excess inductance. A 2 centimeter spacing between cables is required to expose all cabling to the test antennas and limit coupling of signals between cables. The 10 centimeter dimension for cables from the front edge of the ground plane ensures that there is sufficient ground plane surface below the first cable to be effective. The 5 centimeter standoffs standardize loop areas available for coupling and capacitance to the ground plane. The standoffs represent routing and clamping of cables in actual installations a fixed distance from structure.

In some military applications, there can be over 2000 cables associated with a subsystem. In most cases where large number of cables are involved, there will be many identical cable interfaces connected to identical circuitry. Testing of every cable interface is not necessary in this situation. The EMITPP should document instances where these circumstances exist and should propose which cables are to be included in the setup and to be tested.

40.8.5.2 (4.8.5.2) Input power leads. Two meters of input power leads (including returns) shall be routed parallel to the front edge of the setup in the same manner as the interconnecting leads. The power leads shall be connected to the LISNs (see 4.6). Power leads that are part of an interconnecting cable shall be separated out at the EUT connector and routed to the LISNs. After the 2 meter exposed length, the power leads shall be terminated at the LISNs in as short a distance as possible. The total length of power lead from the EUT electrical connector to the LISNs shall not exceed 2.5 meters. All power leads shall be supported 5 centimeter above the ground plane. If the power leads are twisted in the actual installation, they shall be twisted up to the LISNs.

DISCUSSION: Appropriate power lead length is a trade-off between ensuring sufficient length for efficient coupling of radiated signals and maintaining the impedance of the LISNs. To keep a constant setup, it is undesirable to change the power lead length for different test methods. Requiring a 2 meter exposed length is consistent with treatment of interconnecting leads for radiated concerns. Wiring inductance 5 centimeter from a ground plane is approximately 1 microhenry/meter. At 1 MHz this inductance has an impedance of approximately 13 ohms which is significant with respect to the LISN requirement.

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The LISN requirement standardizes impedance for power leads. While signal and control circuits are usually terminated in specified impedances, power circuit impedances are not usually well defined. The LISN requirement applies to all input prime power leads. The LISN requirement does not apply to output power leads. These leads should be terminated after the 2 meter exposed length in a load representing worst-case conditions. This load would normally draw the maximum current allowed for the power source.

The construction of the power cable between the EUT and the LISNs must be in accordance with the requirements of paragraph 4.8.5. For example, if a twisted triplet is used to distribute three phase delta power in the actual installation, the same construction should be used in the test setup. The normal construction must be interrupted over a sufficient length to permit connection to the LISNs.

40.8.6 (4.8.6) Electrical and mechanical interfaces. All electrical input and output interfaces shall be terminated with either the actual equipment from the platform installation or loads which simulate the electrical properties (impedance, grounding, balance, and so forth) present in the actual installation. Signal inputs shall be applied to all applicable electrical interfaces to exercise EUT circuitry. EUTs with mechanical outputs shall be suitably loaded. When variable electrical or mechanical loading is present in the actual installation, testing shall be performed under expected worst case conditions. When active electrical loading (such as a test set) is used, precautions shall be taken to ensure the active load meets the ambient requirements of paragraph 4.4 when connected to the setup, and that the active load does not respond to susceptibility signals. Antenna ports on the EUT shall be terminated with shielded, matched loads.

DISCUSSION: The application of signals to exercise the electrical interface is necessary to effectively evaluate performance. Most electronic subsystems on platforms are highly integrated with large amounts of digital and analog data being transferred between equipment. The use of actual platform equipment for the interfacing eliminates concerns regarding proper simulation of the interface. The interfaces must function properly in the presence of induced levels from susceptibility signals. Required isolation may be obtained by filtering the interface leads at the active load and either shielding the load or placing it outside of the shielded enclosure. The filtering should be selected to minimize the influence on the interface electrical properties specified above. For proper simulation, filtering at the loads should be outside the necessary bandwidth of the interface circuitry.

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Antenna ports are terminated in loads for general setup conditions. Specific test methods address electromagnetic characteristics of antenna ports and required modifications to the test setup.

40.9 (4.9) Operation of EUT. During emission measurements, the EUT shall be placed in an operating mode which produces maximum emissions. During susceptibility testing, the EUT shall be placed in its most susceptible operating mode. For EUTs with several available modes (including software controlled operational modes), a sufficient number of modes shall be tested for emissions and susceptibility such that all circuitry is evaluated.

DISCUSSION: The particular modes selected may vary for different test methods. Considerations for maximum emissions include conditions which cause the EUT to draw maximum prime power current, result in greatest activity in interface circuit operation, and generate the largest current drain on internal digital clock signals. Settings for a radar could be adjusted such that an output waveform results which has the highest available average power. Data bus interfaces could be queried frequently to cause constant bus traffic flow. Any modes of the EUT which are considered mission critical in the installation should be evaluated during susceptibility testing.

A primary consideration for maximum susceptibility is placing the EUT in its most sensitive state for reception of intentional signals (maximum gain). An imaging sensor would normally be evaluated with a scene meeting the most stringent specifications for the sensor. RF receivers are normally evaluated using an input signal at the minimum signal to noise specification of the receiver. An additional consideration is ensuring that all electrical interfaces which intentionally receive data are exercised frequently to monitor for potential responses.

40.9.1 (4.9.1) Operating frequencies for tunable RF equipment. Measurements shall be performed with the EUT tuned to not less than three frequencies within each tuning band, tuning unit, or range of fixed channels, consisting of one mid-band frequency and a frequency within ± 5 percent from each end of each band or range of channels.

DISCUSSION: Tuned circuits and frequency synthesis circuitry inside RF equipment typically vary in characteristics such as response, rejection, and spectral content of emissions as they are set to different frequencies. Several test frequencies are required simply to obtain a sampling of the performance of the EUT across its operating range.

40.9.2 (4.9.2) Operating frequencies for spread spectrum equipment. Operating frequency requirements for two major types of spread spectrum equipment shall be as follows:

- a. Frequency hopping. Measurements shall be performed with the EUT utilizing a hop set which contains 30% of the total possible frequencies. The hop set shall be divided equally into three segments at the low, mid, and high end of the EUT's operational frequency range.
- b. Direct sequence. Measurements shall be performed with the EUT processing data at its highest possible data transfer rate.

DISCUSSION: During testing it is necessary to operate equipments at levels that they will experience during normal field operations to allow for a realistic representation of the emission profile of the EUT during radiated and conducted testing and to provide realistic loading and simulation of the EUT during radiated and conducted susceptibility testing.

Frequency hopping: Utilization of a hopset which is distributed across the entire operational spectrum of the EUT will help assure that internal circuitry dependent on the exact EUT transmit frequency being used is active intermittently during processing of the entire pseudo random stream. The fast operating times of hopping receivers/transmitters versus the allowable measurement times of the measurement receivers being used (paragraph 4.10.4) will allow a representative EUT emission signature to be captured.

Direct sequence: Requiring the utilization of the highest data transfer rate used in actual operation of the EUT should provide a representative worst-case radiated and conducted emission profile. Internal circuitry will operate at its highest processing rate when integrating the data entering the transmitter, and then resolving (disintegrating) the data back once again on the receiver end. Additionally, the data rate will need to be an area of concentration during all susceptibility testing.

40.9.3 (4.9.3) Susceptibility monitoring. The EUT shall be monitored during susceptibility testing for indications of degradation or malfunction. This monitoring is normally accomplished through the use of built-in-test (BIT), visual displays, aural outputs, and other measurements of signal outputs and interfaces. Monitoring of EUT performance through installation of special circuitry in the EUT is permissible; however, these modifications shall not influence test results.

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DISCUSSION: Most EUTs can be adequately monitored through normal visual and aural outputs, self diagnostics, and electrical interfaces. The addition of special circuitry for monitoring can present questions related to its influence on the validity of the test results and may serve as an entry or exit point for electromagnetic energy.

The monitoring procedure needs to be specified in the EMITP and needs to include allowances for possible weaknesses in the monitoring process to assure the highest probability of finding regions of susceptibility.

40.10 (4.10) Use of measuring equipment. Measuring equipment shall be as specified in the individual test methods of this standard. Any frequency selective measurement receiver may be used for performing the testing described in this standard provided that the receiver characteristics (that is, sensitivity, selection of bandwidths, detector functions, dynamic range, and frequency of operation) meet the constraints specified in this standard and are sufficient to demonstrate compliance with the applicable limits of MIL-STD-461. Typical instrumentation characteristics may be found in ANSI C63.2

DISCUSSION: Questions frequently arise concerning the acceptability for use of measurement receivers other than instruments that are specifically designated "field intensity meters" or "EMI receivers". Most questions are directed toward the use of spectrum analyzers. These instruments are generally acceptable for use. However, depending on the type, they can present difficulties which are not usually encountered with the other receivers. Sensitivity may not be adequate in some frequency bands requiring that a low noise preamplifier be inserted before the analyzer input. Impulse type signals from the EUT with broad spectral content may overload the basic receiver or preamplifier. The precautions of paragraph 4.7.3 must be observed. Both of these concerns can usually be adequately addressed by the use of a preselector with the analyzer. These devices typically consist of a tunable filter which tracks the analyzer followed by a preamplifier.

ANSI C63.2 represents a coordinated position from industry on required characteristics of instrumentation receivers. This document can be consulted when assessing the performance of a particular receiver.

Many of the test methods require non-specialized instrumentation which is used for many other purposes. The test facility is responsible for selecting instrumentation which has characteristics capable of satisfying the requirements of a particular test method.

Current probes used for EMI testing are more specialized instrumentation. These devices are current transformers with the circuit under test forming a single turn primary. They are designed to be terminated in 50 ohms. Current probes are calibrated using transfer impedance which is the ratio of the voltage output of the probe across 50 ohms to the current through the probe. Probes with higher transfer impedance provide better sensitivity. However, these probes also result in more series impedance added to the circuit with a greater potential to affect the electrical current level. The series impedance added by the probe is the transfer impedance divided by the number of turns in the secondary winding on the probe. Typical transfer impedances are 5 ohms or less. Typical added series impedance is 1 ohm or less.

40.10.1 (4.10.1) Detector. A peak detector shall be used for all frequency domain emission and susceptibility measurements. This device detects the peak value of the modulation envelope in the receiver bandpass. Measurement receivers are calibrated in terms of an equivalent root mean square (RMS) value of a sine wave that produces the same peak value. When other measurement devices such as oscilloscopes, non-selective voltmeters, or broadband field strength sensors are used for susceptibility testing, correction factors shall be applied for test signals to adjust the reading to equivalent RMS values under the peak of the modulation envelope.

DISCUSSION: The function of the peak detector and the meaning of the output indication on the measurement receiver are often confusing. Although there may appear to be an inherent discrepancy in the use of the terms "peak" and "RMS" together, there is no contradiction. All detector functions (that is peak, carrier, field intensity, and quasi-peak) process the envelope of the signal present in the receiver intermediate frequency (IF) section. All outputs are calibrated in terms of an equivalent RMS value. For a sine wave input to the receiver, the signal envelope in the IF section is a DC level and all detectors produce the same indicated RMS output. Calibration in terms of RMS is necessary for consistency. Signal sources are calibrated in terms of RMS. If a 0 dBm (107 dB μ V) unmodulated signal is applied to the receiver, the receiver must indicate 0 dBm (107 dB μ V).

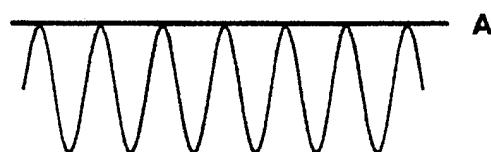
If there is modulation present on the signal applied to the receiver, the detectors respond differently. The IF section of the receiver sees the portion of the applied signal within the bandwidth limits of the IF. The peak detector senses the largest level of the signal envelope in the IF and displays an output equal to the RMS value of a sine wave with the same peak. The specification of a peak detector ensures that the worst case condition for emission data is obtained. A carrier detector

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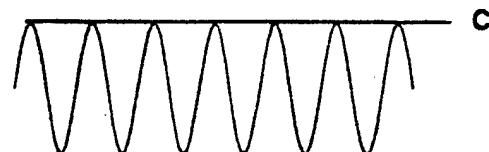
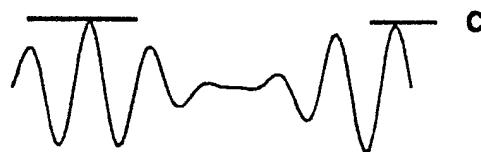
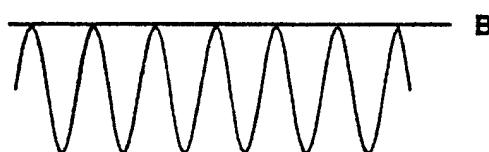
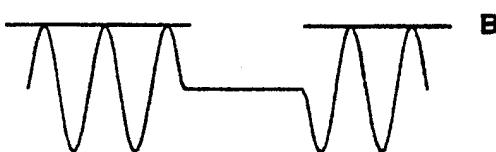
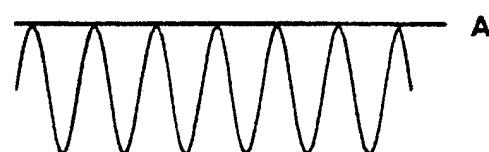
averages the modulation envelope based on selected charge and discharge time constants.

Figure A-1 shows the peak detector output for several modulation waveforms. An item of interest is that for a square wave modulated signal, which can be considered a pulse type modulation, the receiver can be considered to be displaying the RMS value of the pulse when it is on. Pulsed signals are often specified in terms of peak power. The RMS value of a signal is derived from the concept of power, and a receiver using a peak detector correctly displays the peak power.

IF SIGNAL



EQUIVALENT SINE WAVE. SAME PEAK



RECEIVER OUTPUT INDICATION WILL BE $\frac{A}{\sqrt{2}}$, $\frac{B}{\sqrt{2}}$, $\frac{C}{\sqrt{2}}$, RESPECTIVELY

FIGURE A-1. Peak detector response.

All frequency domain measurements are standardized with respect to the response that a measurement receiver using a peak detector would provide. Therefore, when instrumentation is used which does not use peak detection, correction factors must be applied for certain signals. For an oscilloscope, the maximum

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amplitude of the modulated sine wave measured from the DC level is divided by 1.414 (square root of 2) to determine the RMS value at the peak of the modulation envelope.

Correction factors for other devices are determined by evaluating the response of the instrumentation to signals with the same peak level with and without modulation. For example, a correction factor for a broadband field sensor can be determined as follows. Place the sensor in an unmodulated field and note the reading. Apply the required modulation to the field ensuring that the peak value of the field is the same as the unmodulated field. For pulse type modulation, most signal sources will output the same peak value when modulation is applied. Amplitude modulation increases the peak amplitude of the signal and caution must be observed. Note the new reading. The correction factor is simply the reading with the unmodulated field divided by the reading with the modulated field. If the meter read 10 volts/meter without modulation and 5 volts/meter with modulation, the correction factor is 2. The evaluation should be tried at several frequencies and levels to ensure that a consistent value is obtained. When subsequently using the sensor for measurements with the evaluated modulation, the indicated reading is multiplied by the correction factor to obtain the correct reading for peak detection.

40.10.2 (4.10.2) Computer-controlled receivers. A description of the operations being directed by software for computer-controlled receivers shall be included in the EMITP required by MIL-STD-461. Verification techniques used to demonstrate proper performance of the software shall also be included.

DISCUSSION: Computer software obviously provides excellent opportunities for automating testing. However, it also can lead to errors in testing if not properly used or if incorrect code is present. It is essential that users of the software understand the functions it is executing, know how to modify parameters (such as transducer or sweep variables) as necessary, and perform sanity checks to ensure that the overall system performs as expected.

40.10.3 (4.10.3) Emission testing.

40.10.3.1 (4.10.3.1) Bandwidths. The measurement receiver bandwidths listed in Table II shall be used for emission testing. These bandwidths are specified at the 6 dB down points for the overall selectivity curve of the receivers. Video filtering shall not be used to bandwidth limit the receiver response. If a controlled video bandwidth is available on the measurement receiver, it shall be set to its greatest value. Larger bandwidths may be used; however, they may result in higher

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measured emission levels. NO BANDWIDTH CORRECTION FACTORS SHALL BE APPLIED TO TEST DATA DUE TO THE USE OF LARGER BANDWIDTHS.

TABLE II. Bandwidth and Measurement Time.

Frequency Range	6 dB Bandwidth	Dwell Time	Minimum Measurement Time Analog Measurement Receiver
30 Hz - 1 kHz	10 Hz	0.15 sec	0.015 sec/Hz
1 kHz - 10 kHz	100 Hz	0.015 sec	0.15 sec/kHz
10 kHz - 250 kHz	1 kHz	0.015 sec	0.015 sec/kHz
250 kHz - 30 MHz	10 kHz	0.015 sec	1.5 sec/MHz
30 MHz - 1 GHz	100 kHz	0.015 sec	0.15 sec/MHz
Above 1 GHz	1 MHz	0.015 sec	15 sec/GHz

DISCUSSION: The bandwidths specified in Table II are consistent with the recommended available bandwidths and the bandwidth specifications technique for receivers contained in ANSI C63.2. Existing receivers have bandwidths specified in a number of different ways. Some are given in terms of 3 dB down points. The 6 dB bandwidths are usually about 40% greater than the 3 dB values. Impulse bandwidths are usually very similar to the 6 dB bandwidths. For gaussian shaped bandpasses, the actual value is 6.8 dB.

In order not to restrict the use of presently available receivers which do not have the specified bandwidths, larger bandwidths are permitted. The use of larger bandwidths can produce higher detected levels for wide bandwidth signals. The prohibition against the use of correction factors is included to avoid any attempts to classify signals. This version of the standard has eliminated the concept of classification of emissions as broadband or narrowband in favor of fixed bandwidths and single limits specified in MIL-STD-461. Emission classification was a controversial area often poorly understood and handled inconsistently among different facilities.

40.10.3.2 (4.10.3.2) Emission identification. All emissions regardless of characteristics shall be measured with the measurement receiver bandwidths specified in Table II and compared against the limits in MIL-STD-461. Identification of emissions with regard to narrowband or broadband categorization is not applicable.

DISCUSSION: Requirements for specific bandwidths and the use of single limits are intended to resolve a number of problems.

Previous versions of this standard had no controls on required bandwidths and MIL-STD-461 provided both narrowband and broadband limits over much of the frequency range of most emission requirements. The significance of the particular bandwidths chosen for use by a test facility were addressed by classification of the appearance of the emissions with respect to the chosen bandwidths. Emissions considered to be broadband had to be normalized to equivalent levels in a 1 MHz bandwidth. The bandwidths and classification techniques used by various facilities were very inconsistent and resulted in a lack of standardization. The basic issue of emission classification was often poorly understood and implemented. Requiring specific bandwidths with a single limit eliminates any need to classify emissions.

An additional problem is that emission profiles from modern electronics are often quite complex. Some emission signatures have frequency ranges where the emissions exhibit white noise characteristics. Normalization to a 1 MHz bandwidth using spectral amplitude assumptions based on impulse noise characteristics is not technically correct. Requiring specific bandwidths eliminates normalization and this discrepancy.

40.10.3.3 (4.10.3.3) Frequency scanning. For emission measurements, the entire frequency range for each applicable test shall be scanned. Minimum measurement time for analog measurement receivers during emission testing shall be as specified in Table II. Synthesized measurement receivers shall step in one-half bandwidth increments or less, and the measurement dwell time shall be as specified in Table II.

DISCUSSION: For each emission test, the entire frequency range as specified in the applicable portion of MIL-STD-461 must be scanned to ensure that all emissions are measured.

Continuous frequency coverage is required for emission testing. Testing at discrete frequencies is not acceptable unless otherwise stated in a particular test method. The minimum scan times listed in Table II are based on two considerations. The first consideration is the response time of a particular bandwidth to an applied signal. This time is $1/(filter\ bandwidth)$. The second consideration is the potential rates (that is modulation, cycling, and processing) at which electronics operate and the need to detect the worst case emission amplitude. Emission profiles usually vary with time. Some signals are present only at certain intervals and others vary in amplitude. For example, signals commonly present in emission profiles are harmonics of microprocessor clocks. These harmonics are very stable in frequency; however, their amplitude tends to change as various circuitry is exercised and current distribution changes.

The first entry in the table for analog measurement receivers of 0.015 sec/Hz for a bandwidth of 10 Hz is the only one limited by the response time of the measurement receiver bandpass. Therefore, as the receiver tunes, the receiver bandpass must include any particular frequency for 0.1 seconds implying that the minimum scan time = 0.1 seconds/10 Hz = 0.01 seconds. The value in the table has been increased to 0.015 seconds/Hz to ensure adequate time. This increase by a multiplication factor of 1.5 results in the analog receiver having a frequency in its bandpass for 0.15 seconds as it scans. This value is the dwell time specified in the table for synthesized receivers. Since synthesized receivers are required to step in one-half bandwidth increments or less and dwell for 0.15 seconds, test time for synthesized receivers will be greater than analog receivers.

The measurement times for other table entries are controlled by the requirement that the receiver bandpass include any specific frequency for a minimum of 15 milliseconds (dwell time in table), which is associated with a potential rate of variation of approximately 60 Hz. As the receiver tunes, the receiver bandpass is required to include any particular frequency for the 15 milliseconds. For the fourth entry in the table of variation 15 seconds/MHz for a 10 kHz bandwidth, the minimum measurement time is 0.015 seconds/0.01 MHz = 1.5 seconds/MHz. A calculation based on the response time of the receiver would yield a response time of 1/bandwidth = 1/10 kHz = 0.0001 seconds and a minimum measurement time of 0.0001 seconds/0.01 MHz = 0.01 seconds/MHz. The longer measurement time of 1.5 seconds/MHz is specified in the table. If the specified measurement times are not adequate to capture the maximum amplitude of the EUT emissions, longer measurement times should be implemented.

Caution must be observed in applying the measurement times. The specified parameters are not directly available on measurement receiver controls and must be interpreted for each particular receiver. Also, the specified measurement times may be too fast for some data gathering devices such as real-time X-Y recording. Measurement receiver peak hold times must be sufficiently long for the mechanical pen drive on X-Y recorders to reach the detected peak value. In addition, the scan speed must be sufficiently slow to allow the detector to discharge after the signal is detuned so that the frequency resolution requirements of paragraph 4.10.6 are satisfied.

40.10.3.4 (4.10.3.4) Emission data presentation. Amplitude versus frequency profiles of emission data shall be automatically and continuously plotted. The applicable limit shall be displayed on the plot. Manually gathered data is not acceptable except for plot verification. The plotted data for emission

measurements shall provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB. The above resolution requirements shall be maintained in the reported results of the EMITR.

DISCUSSION: Previous versions of this standard permitted data to be taken at the three frequencies per octave for the highest amplitude emissions. This approach is no longer acceptable. Continuous displays of amplitude versus frequency are required. This information can be generated in a number of ways. The data can be plotted real-time as the receiver scans. The data can be stored in computer memory and later dumped to a plotter. Photographs of video displays are acceptable; however, it is generally more difficult to meet resolution requirements and to reproduce data in this form for submittal in an EMITR.

Placement of limits can be done in several ways. Data may be displayed with respect to actual MIL-STD-461 limit dimensions (such as $\text{dB}\mu\text{V}/\text{m}$) with transducer, attenuation and cable loss corrections made to the data. An alternative is to plot the raw data in $\text{dB}\mu\text{V}$ (or dBm) and convert the limit to equivalent $\text{dB}\mu\text{V}$ (or dBm) dimensions using the correction factors. This second technique has the advantage of displaying the proper use of the correction factors. Since both the emission level and the required limit are known, a second party can verify proper placement. Since the actual level of the raw data is not available for the first case, this verification is not possible.

An example of adequate frequency and amplitude resolution is shown in Figure A-2. 1% frequency resolution means that two sinusoidal signals of the same amplitude separated by 1% of the tuned frequency are resolved in the output display so that they both can be seen. As shown in the figure, 1% of the measurement frequency of 5.1 MHz is 0.051 MHz and a second signal at 5.151 MHz (1 dB different in amplitude on the graph) is easily resolved in the display. The "2 times the measurement receiver bandwidth" criteria means that two sinusoidal signals of the same amplitude separated by twice the measurement receiver bandwidth are resolved. For the example shown in Figure A-2, the bandwidth is 0.01 MHz and 2 times this value is 0.02 MHz. Therefore, the 1% criterion is less stringent and is applicable. 1 dB amplitude resolution means that the amplitude of the displayed signal can be read within 1 dB. As shown in the figure, the reviewer can determine whether the signal amplitude is 60 $\text{dB}\mu\text{V}$ or 61 $\text{dB}\mu\text{V}$.

The difference between resolution and accuracy is sometimes confusing. Paragraph 4.1.1 of the standard requires 3 dB measurement system accuracy for amplitude while paragraph 4.10.6 of the standard requires 1 dB amplitude resolution. Accuracy is an indication how precisely a value needs to be known while

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resolution is an indication of the ability to discriminate between two values. A useful analogy is reading time from a watch. A watch typically indicates the time within one second (resolution) but may be 30 seconds different than the absolute correct time (accuracy).

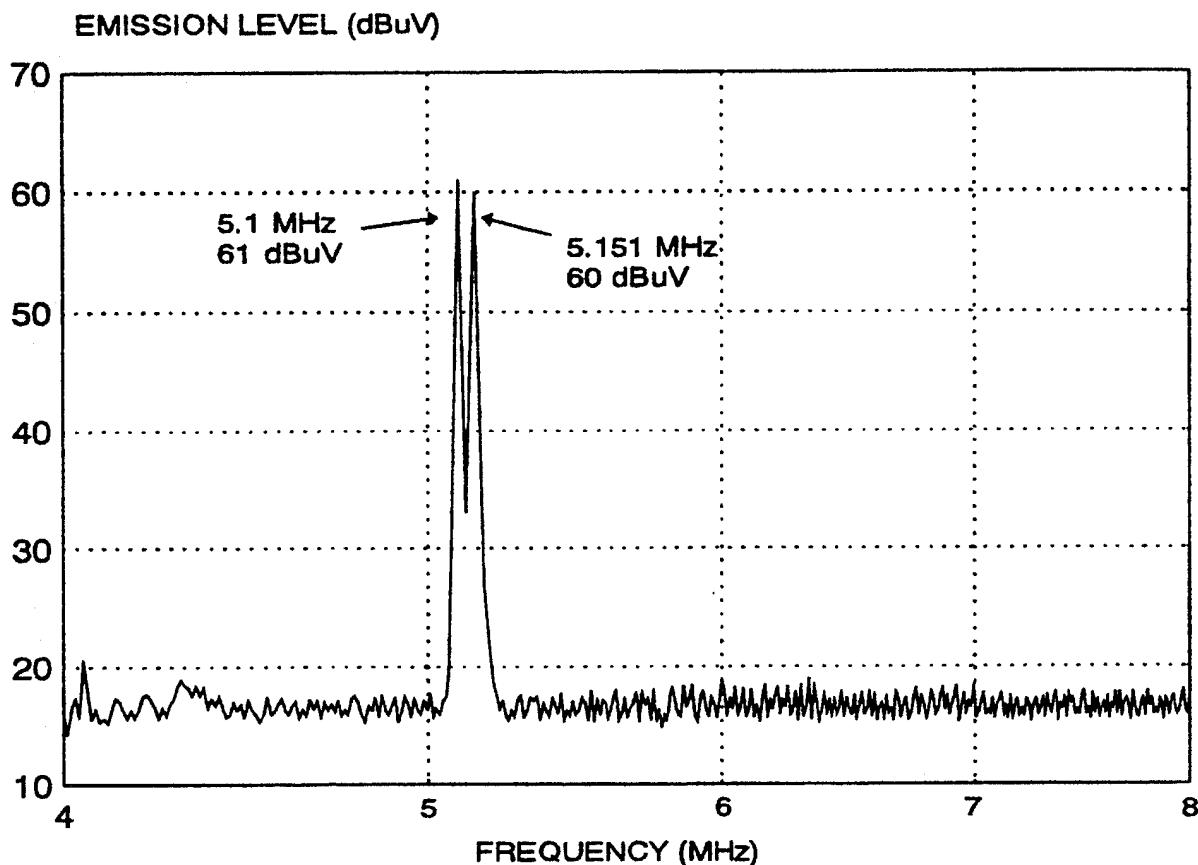


FIGURE A-2. Example of data presentation resolution.

40.10.4 (4.10.4) Susceptibility testing.

40.10.4.1 (4.10.4.1) Frequency scanning. For susceptibility measurements, the entire frequency range of each applicable test shall be scanned. For swept frequency susceptibility testing, frequency scan rates and frequency step sizes of signal sources shall not exceed the values listed in Table III. The rates and step sizes are specified in terms of a multiplier of the tuned frequency (f_0) of the signal source. Analog scans refer to signal sources which are continuously tuned. Stepped scans refer to signal sources which are sequentially tuned to discrete frequencies. Stepped scans shall dwell at each tuned frequency for a minimum of 1 second. Scan

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rates and step sizes shall be decreased when necessary to permit observation of a response.

DISCUSSION: For any susceptibility test performed in the frequency domain, the entire frequency range as specified in MIL-STD-461 must be scanned to ensure that all potentially susceptible frequencies are evaluated.

The scan rates and step sizes in Table III are structured to allow for a continuous change in value with frequency for flexibility. Computerized test systems could be programmed to change values very frequently. A more likely application is to block off selected bands for scanning and to base selections of scan rate or step size on the lowest frequency. For example, if 1 - 2 GHz were selected, the maximum scan rate would be $(0.002 \times 1 \text{ GHz})/\text{sec}$ which equals 2 MHz/sec and the maximum step size would be $0.001 \times 1 \text{ GHz}$ which equals 1 MHz. Both automatic and manual scanning are permitted.

TABLE III. Susceptibility Scanning.

Frequency Range	Analog Scans Maximum Scan Rate	Stepped Scans Maximum Step Size
30 Hz - 1 MHz	0.02 f _o /sec	0.01 f _o
1 MHz - 30 MHz	0.01 f _o /sec	0.005 f _o
30 MHz - 1 GHz	0.005 f _o /sec	0.0025 f _o
1 GHz - 8 GHz	0.002 f _o /sec	0.001 f _o
8 GHz - 40 GHz	0.001 f _o /sec	0.0005 f _o

The two primary areas of concern for frequency scanning for susceptibility testing are response times for EUTs to react to stimuli and how sharply the responses tune with frequency, normally expressed as quality factor (Q). Both of these items have been considered in the determination of the scan rates and step sizes in Table III. The table entries are generally based on the assumption of a maximum EUT response time of one second and Q values of 50, 100, 200, 500, and 1000 (increasing values as frequency increases in Table III). Since EUT responses are more likely to occur in approximately the 1 to 200 MHz range due to efficient cable coupling based on wavelength considerations, Q values have been increased somewhat to slow the scan and allow additional time for observation of EUT responses. More detailed discussions on these items follow.

The assumption of a maximum response time of one second is considered to be appropriate for a large percentage of possible cases. There are several considerations. While the electronics

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processing the interfering signal may respond quickly, the output display may take some time to react. Outputs which require mechanical motion such as meter movements or servo driven devices will generally take longer to show degradation effects than electronic displays such as video screens. Another concern is that some EUTs will only be in particularly susceptible states periodically. For example, sensors feeding information to a microprocessor are typically sampled at specific time intervals. It is important that the susceptibility stimuli be located at any critical frequencies when the sensor is sampled. The time intervals between steps and sweep rates in Table III may need to be modified for EUTs with unusually long response times.

Some concern has been expressed on the susceptibility scan rates and the impact that they would have on the length of time required to conduct a susceptibility test. The criteria of Table III allow the susceptibility scan rate to be adjusted continually as the frequency is increased; however, as a practical matter, the rate would most likely only be changed once every octave or decade. As an example, Table A-I splits the frequency spectrum up into ranges varying from octaves to decades and lists the minimum time required to conduct a susceptibility test for an analog scan. The scan rate for each range is calculated based on the start frequency for the range. The total test time to run RS103 from 1 MHz to 18 GHz is 76.3 minutes. A similar calculation for a stepped scan results in a total test time which is 2 times this value or 152.6 minutes. It must be emphasized that the scan speeds should be slowed down if the EUT response time or Q are more critical than those used to establish the values in Table III.

Q is expressed as f_o/BW where f_o is the tuned frequency and BW is the width in frequency of the response at the 3 dB down points. For example, if a response occurred at 1 MHz at a susceptibility level of 1 volt and the same response required 1.414 volts (3 dB higher in required drive) at 0.95 and 1.05 MHz, the Q would be $1 \text{ MHz}/(1.05 - 0.95 \text{ MHz})$ or 10. Q is primarily influenced by resonances in filters, interconnecting cabling, physical structure, and cavities. The assumed Q values are based on observations from various types of testing. The step sizes in Table III are one half of the 3 dB bandwidths of the assumed value of Q ensuring that test frequencies will lie within the resonant responses.

Below approximately 200 MHz, the predominant contributors are cable and interface filter resonances. There is loading associated with these resonances which dampens the responses and limits most values of Q to less than 50. Above 200 MHz, structural resonances of enclosures and housings start playing a role and have higher values of Q due to less dampening. Above approximately 1 GHz, aperture coupling with excitation of

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cavities will become dominant. Values of Q are dependent on frequency and on the amount of material contained in the cavity. Larger values of Q result when there is less material in the volume. A densely packaged electronics enclosure will exhibit significantly lower values of Q than an enclosure with a higher percentage of empty volume. Q is proportional to Volume/(Surface Area X Skin Depth). The value of Q also tends to increase with frequency as the associated wavelength becomes smaller. EUT designs with unusual configurations which result in high Q characteristics may require that the scan rates and step sizes in Table III be decreased for valid testing.

TABLE A-I. Susceptibility Testing Times

Frequency Range	Maximum Scan Rate	Actual Scan Time
30 Hz - 100 Hz	0.6 Hz/sec	1.9 min
100 Hz - 1 kHz	2.0 Hz/sec	7.5 min
1 kHz - 10 kHz	20.0 Hz/sec	7.5 min
10 kHz - 100 kHz	200 Hz/sec	7.5 min
100 kHz - 1 MHz	2 kHz/sec	7.5 min
1 MHz - 5 MHz	10 kHz/sec	6.6 min
5 MHz - 30 MHz	50 kHz/sec	8.3 min
30 MHz - 100 MHz	150 kHz/sec	7.8 min
100 MHz - 200 MHz	500 kHz/sec	3.3 min
200 MHz - 400 MHz	1 MHz/sec	3.3 min
400 MHz - 1 GHz	2 MHz/sec	5.0 min
1 GHz - 2 GHz	2 MHz/sec	8.4 min
2 GHz - 4 GHz	4 MHz/sec	8.4 min
4 GHz - 8 GHz	8 MHz/sec	8.4 min
8 GHz - 12 GHz	8 MHz/sec	8.4 min
12 GHz - 18 GHz	12 MHz/sec	8.4 min
18 GHz - 30 GHz	18 MHz/sec	11.1 min
30 GHz - 40 GHz	30 MHz/sec	5.6 min

RF processing equipment presents a special case requiring unique treatment. Intentionally tuned circuits for processing RF can have very high values of Q. For example, a circuit operating

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at 1 GHz with a bandwidth of 100 kHz has a Q of 1 GHz/100 kHz or 10,000.

Automatic leveling used to stabilize the amplitude of a test signal for stepped scans may require longer dwell times than one second at discrete frequencies. The signal will take time to settle and any EUT responses during the leveling process should be ignored.

40.10.4.2 (4.10.4.2.) Modulation of susceptibility signals. Susceptibility test signals above 10 kHz shall be pulse modulated at a 1 kHz rate with a 50% duty cycle unless otherwise specified in an individual test method of this standard.

DISCUSSION: Modulation is usually the effect which degrades EUT performance. The wavelengths of the RF signal cause efficient coupling to electrical cables and through apertures (at higher frequencies). Nonlinearities in the circuit elements detect the modulation on the carrier. The circuits may then respond to the modulation depending upon detected levels, circuit bandpass characteristics, and processing features.

Pulse modulation at a 1 kHz rate, 50% duty cycle, (alternately termed 1 kHz square wave modulation) is specified for several reasons. One kHz is within the bandpass of most analog circuits such as audio or video. The fast rise and fall times of the pulse causes the signal to have significant harmonic content high in frequency and can be detrimental to digital circuits. Response of electronics has been associated with energy present and a square wave results in high average power. The modulation encompasses many signal modulations encountered in actual use. The square wave is a severe form of amplitude modulation used in communications and broadcasting. It also is a high duty cycle form of pulse modulation representative of radars.

Previous versions of MIL-STD-461 required that the worst case modulation for the EUT be used. Worst case modulation usually was not known or determined. Also, worst case modulation may not be related to modulations seen in actual use or may be very specialized. The most typical modulations used below approximately 400 MHz have been amplitude modulation at either 400 or 1000 Hz (30 to 80%) or pulse modulation, 50% duty cycle, at 400 or 1000 Hz. These same modulations have been used above 400 MHz together with pulse modulation at various pulse widths and pulse repetition frequencies. Continuous wave (CW - no modulation) has also occasionally been used. CW typically produces a detected DC level in the circuitry and affects certain types of circuits. In general, experience has shown that modulation is more likely to cause degradation. CW should be included as an additional requirement when assessing circuits

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which respond only to heat such as electroexplosive devices. CW should not normally be used as the only condition.

40.10.4.3 (4.10.4.3) Thresholds of susceptibility. When susceptibility indications are noted in EUT operation, a threshold level shall be determined where the susceptible condition is no longer present. Thresholds of susceptibility shall be determined as follows:

- a. When a susceptibility condition exists, reduce the interference signal until the EUT recovers.
- b. Reduce the interference signal by an additional 6 dB.
- c. Gradually increase the interference signal until the susceptibility condition reoccurs. The resulting level is the threshold of susceptibility.
- d. Record this level, frequency range of occurrence, frequency and test level of greatest susceptibility, and other test parameters, as applicable.

DISCUSSION: It is usually necessary to test at levels above MIL-STD-461 requirements to ensure that the test signal is at least at the required level. Determination of a threshold of susceptibility is necessary when degradation is present to assess whether requirements are met. This information should be included in the EMITR. Threshold levels below MIL-STD-461 requirements are unacceptable.

The specified steps to determine thresholds of susceptibility standardize a particular technique. An alternative method sometimes utilized in the past was to use the value of the applied signal where the EUT recovers (step a above) as the threshold. Hysteresis type effects are often present where different values are obtained for the two methods.

40.11 (4.11) Calibration of measuring equipment and antennas. Test equipment and accessories required for measurement in accordance with this standard shall be calibrated under an approved program in accordance with MIL-STD-45662. In particular, measurement antennas, current probes, field sensors, and other devices used in the measurement loop shall be calibrated at least every 2 years unless otherwise specified by the procuring activity, or when damage is apparent. Antenna factors and current probe transfer impedances shall be determined on an individual basis for each device.

DISCUSSION: Calibration is typically required for any measurement device whose characteristics are not verified through

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use of another calibrated item during testing. For example, it is not possible during testing to determine whether an antenna used to measure radiated emissions is exhibiting correct gain characteristics. Therefore, these antennas require periodic calibration. Conversely, a power amplifier used during radiated susceptibility testing often will not require calibration since application of the proper signal level is verified through the use of a separate calibrated field sensing device. Other amplifier applications such as the use of a signal pre-amplifier in front of a measurement receiver would require calibration of the amplifier characteristics since the specific gain versus frequency response is critical and is not separately verified.

40.11.1 (4.11.1) Measurement system test. At the start of each emission test, the complete test system (including measurement receivers, cables, attenuators, couplers, and so forth) shall be verified by injecting a known signal, as stated in the individual test method, while monitoring the system output for the proper indication.

DISCUSSION: The end-to-end system check prior to emission testing is valuable in demonstrating that the overall measurement system is working properly. It evaluates many factors including proper implementation of transducer factors and cable attenuation, general condition and setting of the measurement receiver, damaged RF cables or attenuators, and proper operation of software. Details on implementation are included in the individual test methods.

40.12 (4.12) Antenna factors. Factors for electric field test antennas shall be determined in accordance with SAE ARP-958.

DISCUSSION: SAE ARP-958 provides a standard basis for determining antenna factors for electric field emission testing. A caution needs to be observed in trying to apply these factors in applications other than EMI testing. The two antenna technique for antennas such as the biconical and double ridge horns is based on far field assumptions which are not met over much of the frequency range. Although the factors produce standardized results, the true value of the electric field is not necessarily being provided through the use of the factor. Different measuring sensors need to be used when the true electric field must be known.

50.0 MEASUREMENT PROCEDURES

TEST METHOD CE101:

This test method is used to measure emissions conducted from the EUT on input power leads from 30 Hz to 10 kHz. It is not applicable to power leads which supply power to other equipment. Emission levels are determined by measuring the current present on each power lead.

The LISNs will have little influence on the results of this testing. The circuit characteristics of the LISN will help stabilize measurements near 10 kHz; however, the LISN parameters will not be significant over most of the frequency range of the test.

Current is measured because of the low impedances present over most of the frequency range of the test. Current levels will be somewhat independent of power source impedance variations as long as the impedance of the emission source is significant in relation to the power source impedance. However, at frequencies where the shielded room filters in the test facility resonate (generally between 1 and 10 kHz), influences on measured currents can be expected.

During the measurement system check, the signal generator may need to be supplemented with a power amplifier to obtain the necessary current 6 dB below the MIL-STD-461 limit.

A possible alternative measurement tool in this frequency range is wave analyzer using a Fast Fourier Transform algorithm. Use of this type of instrumentation requires specific approval by the procuring activity.

TEST METHOD CE102:

This test method is used to measure emissions conducted from the EUT on input power leads from 10 kHz to 10 MHz. It is not applicable to power leads which supply power to other equipment. Emission levels are determined by measuring the voltage present at the output port on the LISN.

The power source impedance control provided by the LISN is a critical element of this test. This control is imposed due to wide variances in characteristics of shielded room filters and power line impedances among various test agencies and to provide repeatability through standardization. The LISN standardizes this impedance. The impedance present at the EUT electrical interface is influenced by the circuit characteristics of the

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power lead wires to the LISNs. The predominant characteristic is inductance. The impedance starts to deviate noticeably at approximately 1 MHz where the lead inductance is about 13 ohms.

The upper measurement frequency is limited to 10 MHz because of resonance conditions with respect to the length of the power leads between the EUT and LISN. As noted in paragraph 4.8.5.2 of the main body of the standard, these leads are between 2.0 and 2.5 meters long. Laboratory experimentation and theory show a quarter-wave resonance close to 25 MHz for a 2.5 meter lead. In the laboratory experiment, the impedance of the power lead starts to rise significantly at 10 MHz and peaks at several thousand ohms at approximately 25 MHz. Voltage measurements at the LISN become largely irrelevant above 10 MHz.

The 0.25 microfarad coupling capacitor in the LISN allows approximately 3.6 volts to be developed across the 50 ohm termination on the signal port for 115 volt, 400 Hz, power sources. The 20 dB attenuator is specified in the test method to protect the measurement receiver and to prevent overload. 60 Hz sources pose less of a concern.

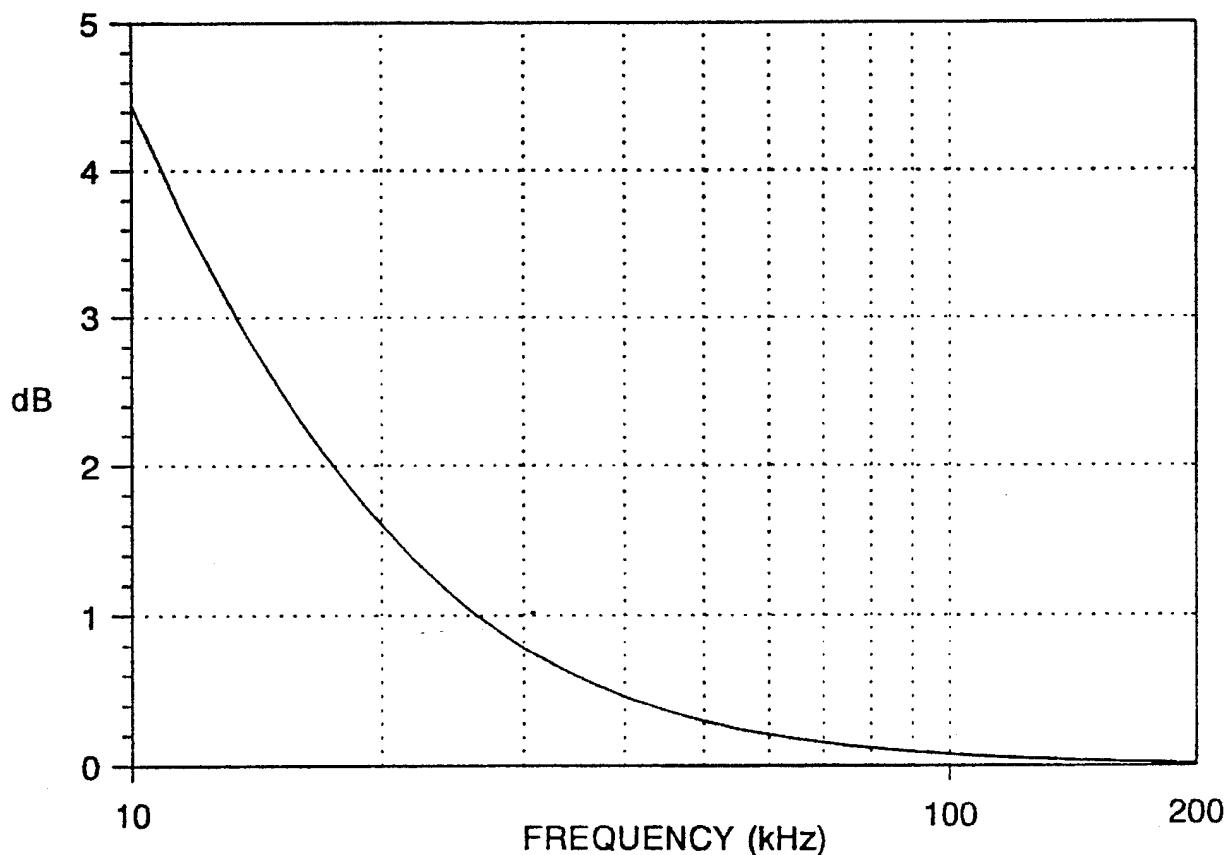


FIGURE A-3. Correction factor for LISN capacitor.

A correction factor must be included in the data reduction to account for the 20 dB attenuator and for voltage drops across the coupling capacitor. This capacitor is in series with a parallel combination of the 50 ohm measurement receiver and the 1 kilohm LISN resistor. The two parallel resistances are equivalent to 47.6 ohms. The correction factor equals $20 \log_{10} ((1 + (7.48 \times 10^{-5})f)^2)^{1/2} / (7.48 \times 10^{-5}f)$ where f is the frequency of interest expressed in Hz. This equation is plotted in Figure A-3. The correction factor is 4.46 dB at 10 kHz and drops rapidly with frequency.

An area of concern for this test method is the potential to overload the measurement receiver due to the current at the power frequency. Overload precautions are discussed in paragraph 4.7.3 of this standard. When an overload condition is predicted or encountered, a rejection filter can be used to attenuate the power frequency. A correction factor must be then included in the emission data to account for the filter loss with respect to frequency.

TEST METHOD CE106:

This test method is used to measure spurious and harmonic outputs appearing at the antenna port of transmitters. It is also used to measure emissions at the antenna port of receivers, amplifiers, and transmitters in the stand-by mode.

Since the test method measures emissions present on a controlled impedance, shielded, transmission line, the measurement results should be largely independent of the test setup configuration. Therefore, it is not necessary to maintain the basic test set described in the main body of this standard.

It is a direct coupled technique and does not consider the effect that the antenna system characteristics will have on actual radiated levels.

Figure CE106-1 is used for receivers, amplifiers, and transmitters in the stand-by mode. The purpose of the attenuator pad in Figure CE106-1 is to establish a low VSWR for more accurate measurements. Its nominal value is 10 dB, but it can be smaller, if necessary, to maintain measurement sensitivity.

The setup in Figure CE106-2 is used for low power transmitters in which the highest intentionally generated frequency does not exceed 26 GHz. The attenuator pad should be approximately 20 dB or large enough to reduce the output level of the transmitter sufficiently so that it does not damage or overload the measurement receiver. The rejection network in the figure is tuned to the fundamental frequency of the EUT and is intended to reduce post-pad transmitter power to a level which

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will not desensitize or induce spurious responses in the measurement receiver. Both the rejection network and RF pad losses must be adjusted to maintain adequate measurement system sensitivity. The total power reaching the measurement receiver input should not exceed the maximum allowable level specified by the manufacturer. All rejection and filter networks must be calibrated over the frequency range of measurement.

The setup of Figure CE106-3 is for transmitters with high average power. For transmitters with an integral antenna, it is usually necessary to measure the spurious emissions by the radiated method RE103.

Some caution needs to be exercised in applying Table II of the main body of this standard. For spurious and harmonic emissions of equipment in the transmit mode, it is generally desirable for the measurement receiver bandwidth to be sufficiently large to include at least 90% of the power of the signal present at a tuned frequency. This condition is required if a comparison is being made to a power requirement in a specification. Spurious and harmonic outputs generally have the same modulation characteristics as the fundamental. Since this method measures relative levels of spurious and harmonic signal with respect to the fundamental, it is not necessary for the measurement receiver to meet the above receiver bandwidth to signal bandwidth criterion. However, if the measurement receiver bandwidth does not meet the criterion and spurious and harmonic outputs are located in frequency ranges where this standard specifies a bandwidth different than that used for the fundamental, the measurement receiver bandwidth should be changed to that used at the fundamental to obtain a proper measurement.

For EUTs having waveguide transmission lines, the measurement receiver needs to be coupled to the waveguide by a waveguide to coaxial transition. Since the waveguide acts as a high-pass filter, measurements are not necessary at frequencies less than $0.8 f_{co}$, where f_{co} is the waveguide cut-off frequency.

TEST METHOD CS101:

This test method is used to verify the ability of the EUT to withstand ripple voltages present on power leads. Since the applied voltage is coupled in series using a transformer, Kirchoff's voltage law requires that the voltage appearing across the transformer output terminals must drop around the circuit loop formed by the EUT input and the power source impedance. The voltage specified by MIL-STD-461 is measured across the EUT input because part of the transformer voltage can be expected to drop across the source impedance.

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Earlier EMI standards introduced a circuit for a phase shift network which was intended to cancel out AC power waveforms and allow direct measurement of the ripple present across the EUT. While these devices very effectively cancel the power waveform, they return the incorrect value of the ripple and are not acceptable for use. The networks use the principle of inverting the phase of the input power waveform, adding it to the waveform (input power plus ripple) across the EUT, and presumably producing only the ripple as an output. For a clean power waveform, the network would perform properly. However, the portion of the ripple which drops across the power source impedance contaminates the waveform and gets recombined with the ripple across the EUT resulting in an incorrect value.

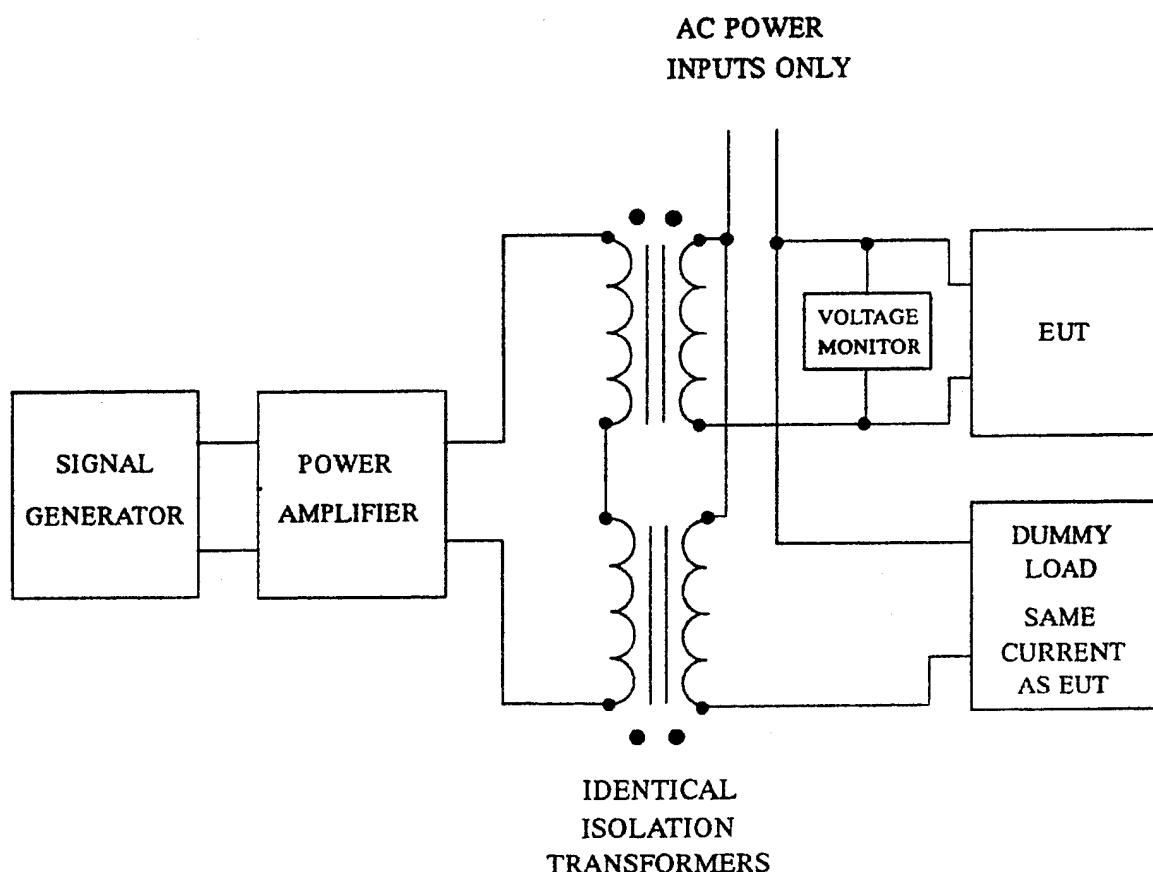


FIGURE A-4. CS101 Power amplifier protection.

Voltages will appear across the primary side of the injection transformer due to the EUT current load at the power frequency. Larger current loads will result in larger voltages

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and are the predominant concern. These voltages can cause potential problems with the power amplifier. The circuit arrangement in Figure A-4 will substantially reduce this voltage and provide protection for the amplifier. This effect is accomplished by using a dummy load equal to the EUT and wiring the additional transformer so that its induced voltage is equal to and 180 degrees out of phase with the induced voltage in the injection transformer. If possible, the dummy load should have the same power factor as the EUT.

The injected signal should be maintained as a sinusoid. Saturation of the power amplifier or coupling transformer may result in a distorted waveform.

TEST METHOD CS103:

This test method determines whether a receiver is free of responses due to intermodulation products produced in the receiver from two signals applied to the antenna port. No test method is provided in the main body of this standard for this requirement. Because of the large variety of receiver designs being developed, the requirements for the specific operational characteristics of a receiver must be established before meaningful test procedures can be developed. Only general testing techniques are discussed in this appendix.

Intermodulation testing can be applied to a variety of receiving subsystems such as receivers, RF amplifiers, transceivers and transponders.

Several receiver front-end characteristics must be known for proper testing for intermodulation responses. These characteristics generally should be determined by test. The maximum signal input that the receiver can tolerate without overload needs to be known to ensure that the test levels are reasonable and that the test truly is evaluating intermodulation effects. The bandpass characteristics of the receiver are important for determining frequencies near the receiver fundamental f_0 that will be excluded from test. Requirements for this test are generally expressed in terms of a relative degree of rejection by specifying the difference in level between potentially interfering signals and the established sensitivity of the receiver under test. Therefore, determination of the sensitivity of the receiver is a key portion of the test.

The basic concept with this test is to combine two out-of-band signals and apply them to the antenna port of the receiver while monitoring the receiver for an undesired response. One of the out-of-band signals is normally modulated with the modulation expected by the receiver. The second signal is normally continuous wave (CW). Figure A-5 shows a general setup for this

test. For applications where the receiver would not provide an indication of interference without a receive signal being present, a third signal can be used at the fundamental. This arrangement may also be suitable for some receivers which process a very specialized type of modulation which would never be expected on an out-of-band signal. An option is for the two out-of-band signals to be CW for this application.

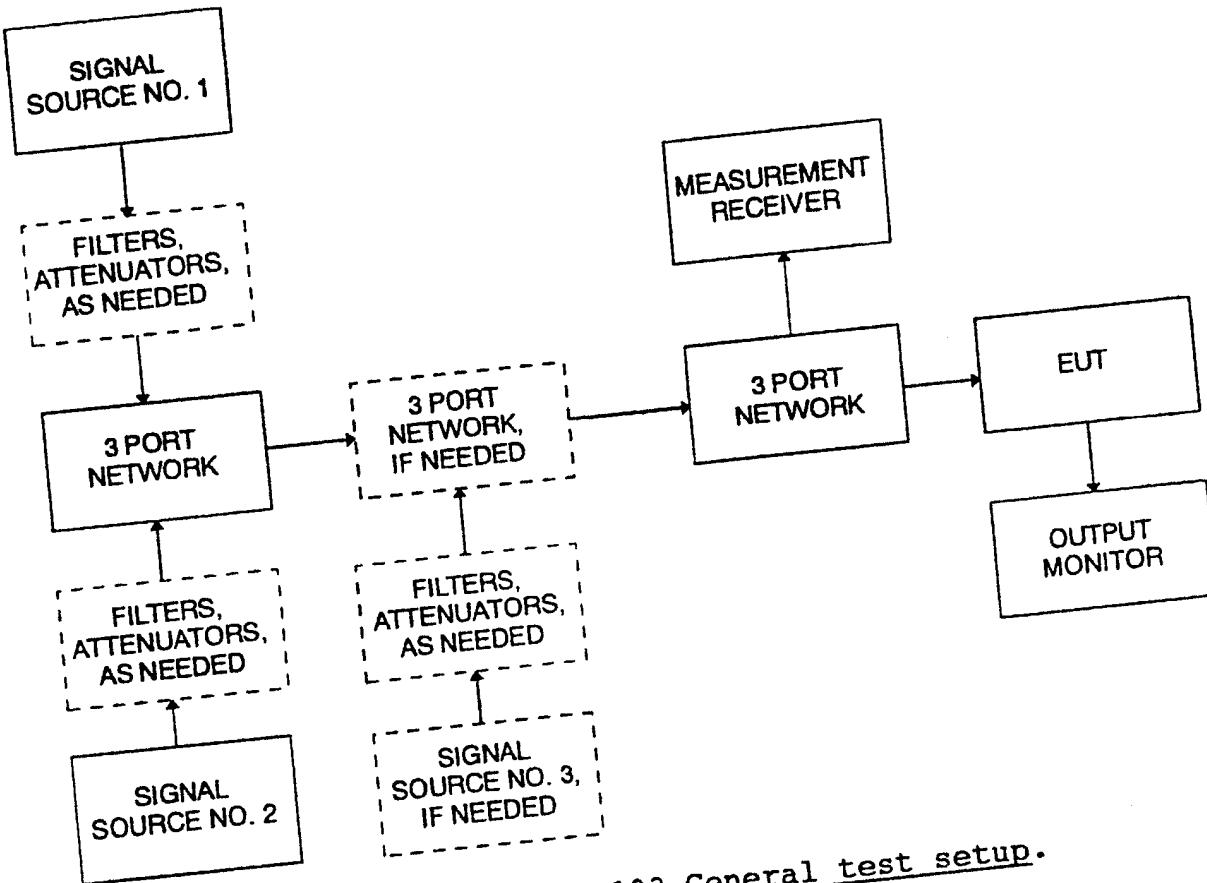


FIGURE A-5. CS103 General test setup.

The frequency of the two out-of-band signals should be set such that $f_o = 2f_1 - f_2$, where f_o is the tuned frequency of the receiver and f_1 and f_2 are the frequencies of the signal sources. This equation represents a third order intermodulation product, which is the most common response observed in receivers. f_1 and f_2 should be swept or stepped over the desired frequency range while maintaining the relationship in the equation. It is important to verify that any responses noted during this test are due to intermodulation responses. Responses can result from simply lack of rejection to one of the applied signals or from harmonics of one of the signal sources. Turning off each signal

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source in turn and noting whether the response remains can demonstrate the source of the response.

For receivers with front-end mixing and filtering in an antenna module, the test may need to be designed to be performed on a radiated basis. All signals would need to be radiated and assurances provided that any observed intermodulation products are due to the receiver and not caused by items in the test area. The EMITP would need to address antenna types, antenna locations, antenna polarizations and field measurement techniques. This test would probably need to be performed in an anechoic chamber.

For frequency hopping receivers, one possible approach is choose an f_0 within the hop set and set up the signals sources as described above. The performance of the receiver could then be evaluated as the receiver hops. If the frequency hopping receiver has a mode of operation using just one fixed frequency, this mode should also be tested.

A common error made in performing this test method is attributing failures to the EUT which are actually harmonics of the signal source or intermodulation products generated in the test setup. Therefore, it is important to verify that the signals appearing at the EUT antenna port are only the intended signals through the use of a measurement receiver as shown in Figure A-5. Damaged, corroded, and faulty components can cause signal distortion resulting in misleading results. Monitoring will also identify path losses caused by filters, attenuators, couplers, and cables.

Typical data for this test method for the EMITR are the sensitivity of the receiver, the levels of the signal sources, frequency ranges swept, operating frequencies of the receivers, and frequencies and threshold levels associated with any responses.

TEST METHOD CS104:

This test method determines whether a receiver is free of responses from out-of-band signals applied to the antenna port. No test method is provided in the main body of this standard for this requirement. Because of the large variety of receiver designs being developed, the requirements for the specific operational characteristics of a receiver must be established before meaningful test procedures can be developed. Only general testing techniques are discussed in this appendix.

Front-end rejection testing can be applied to a variety of receiving subsystems such as receivers, RF amplifiers, transceivers and transponders.

Several receiver front-end characteristics must be known for proper testing. These characteristics generally should be determined by test. The maximum signal input that the receiver can tolerate without overload needs to be known to ensure that the test levels are reasonable. The bandpass characteristics of the receiver are important for determining frequencies near the receiver fundamental that will be excluded from testing. Requirements for this test are often expressed in terms of a relative degree of rejection by specifying the difference in level between a potentially interfering signals and the established sensitivity of the receiver under test. Therefore, determination of the sensitivity of the receiver is a key portion of the test.

The basic concept with this test method is to apply out-of-band signals to the antenna port of the receiver while monitoring the receiver for degradation. Figure A-6 shows a general test setup for this test. There are two common techniques used for performing this test using either one or two signal sources. For the one signal source method, the signal source is modulated with the modulation expected by the receiver. It is then swept over the appropriate frequency ranges while the receiver is monitored for unintended responses. With the two signal source method, a signal appropriately modulated for the two signal source method, a tuned frequency of the receiver. The receiver is applied at the normally specified to be close to the sensitivity of the receiver. The second signal is unmodulated and is swept over the appropriate frequency ranges while the receiver is monitored for any change in its response to the intentional signal.

The two signal source method is more appropriate for most receivers. The one signal source method may be more appropriate for receivers which search for a signal to capture since they may respond differently once a signal has been captured. Some receivers may need to be evaluated using both methods to be completely characterized.

For frequency hopping receivers, one possible approach is to use a one signal method as if the EUT did not have a tuned frequency (include frequency scanning across the hop set) to evaluate the jamming/interference resistance of the receiver. If a frequency hopping receiver has a mode of operation using just one fixed frequency, this mode should also be tested.

For receivers with front-end mixing and filtering in an antenna module, the test may need to be designed to be performed on a radiated basis. All signals would need to be radiated and assurances provided that any observed responses are due to the receiver and not caused by items in the test area. The EMITP would need to address antenna types, antenna locations, antenna

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polarizations, and field measurement techniques. This test would probably need to be performed in an anechoic chamber.

A common error made in performing this test method is attributing failures to the EUT which are actually harmonics or spurious outputs of the signal source. Therefore, it is important to verify that the signals appearing at the EUT antenna port are only the intended signals through the use of a measurement receiver as shown in Figure A-6. Damaged, corroded, and faulty components can cause signal distortion resulting in misleading results. Monitoring will also identify path losses caused by filters, attenuators, and cables.

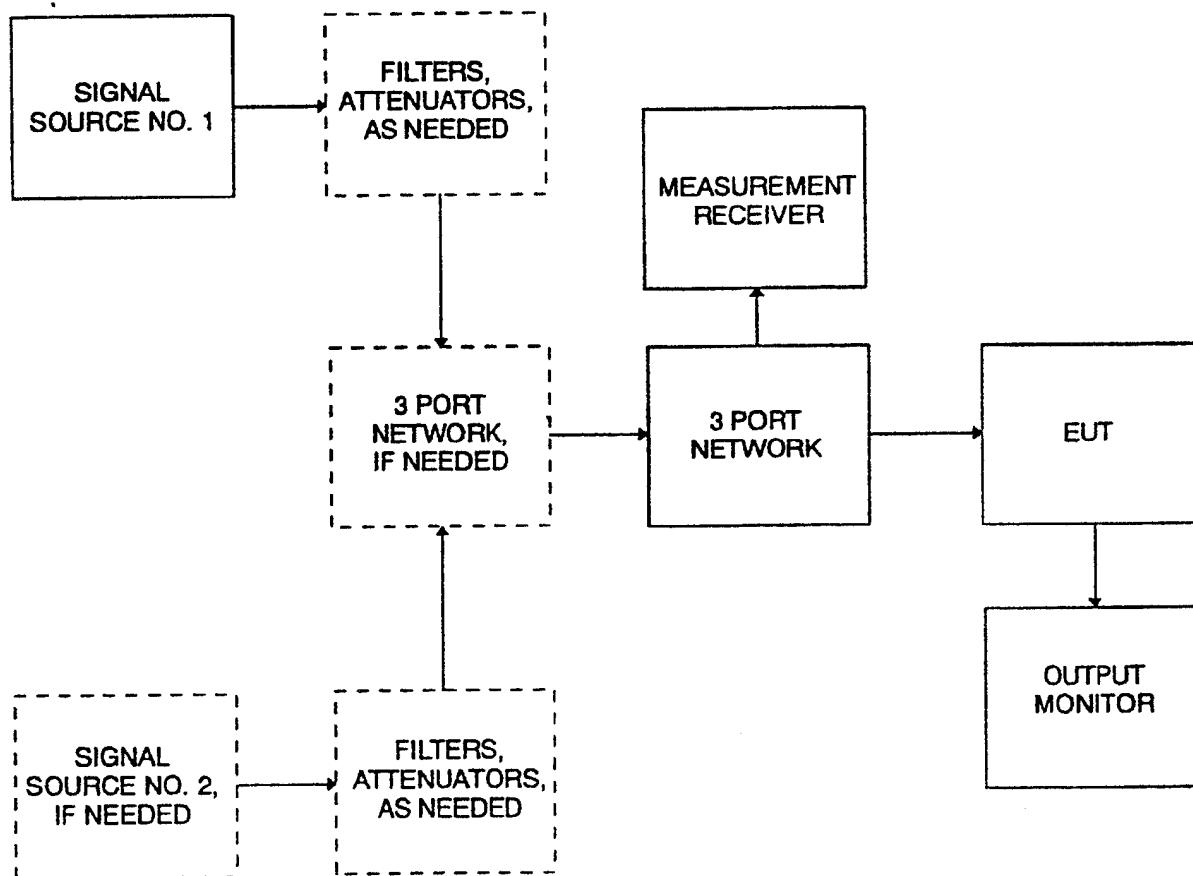


FIGURE A-6. CS104 General test setup.

Typical data for this test method for the EMITR are the sensitivity of the receiver, the levels of the signal sources, frequency ranges swept, operating frequencies of the receivers, degree of rejection (dB), and frequencies and threshold levels associated with any responses.

TEST METHOD CS105:

This test method determines whether a receiver is free of responses due to modulation of an out-of-band signal being transferred to an in-band signal at the antenna port. No test method is provided in the main body of this standard for this requirement. Because of the large variety of receiver designs being developed, the requirements for the specific operational characteristics of a receiver must be established before meaningful test procedures can be developed. Only general testing techniques are discussed in this appendix.

Cross modulation testing should be applied only to receiving subsystems such as receivers, RF amplifiers, transceivers and transponders which extract information from the amplitude modulation of a carrier.

Several receiver front-end characteristics must be known for proper testing for cross modulation responses. These characteristics generally should be determined by test. The maximum signal input that the receiver can tolerate without overload needs to be known to ensure that the test levels are reasonable. The bandpass characteristics of the receiver are important for determining frequencies near the receiver fundamental that will be excluded from test. Requirements for this test are generally expressed in terms of a relative degree of rejection by specifying the difference in level between potentially interfering signals and the established sensitivity of the receiver under test. Therefore, determination of the sensitivity of the receiver is a key portion of the test.

The basic concept with this test is to apply a modulated signal out-of-band to the receiver and to determine whether the modulation is transferred to an unmodulated signal at the receiver's tuned frequency resulting in an undesired response. There may be cases where the in-band signal needs to be modulated if the receiver characteristics so dictate. The level of the in-band signal is normally adjusted to be close to the receiver's sensitivity. The out-of-band signal is modulated with the modulation expected by the receiver. It is then swept over the appropriate frequency ranges while the receiver is monitored for unintended responses. Testing has typically been performed over a frequency range \pm the receiver intermediate frequency (IF) centered on the receiver's tuned frequency. Figure A-7 shows a general setup for this test.

For receivers with front-end mixing and filtering in an antenna module, the test may need to be designed to be performed on a radiated basis. All signals would need to be radiated and assurances provided that any responses are due to the receiver and not caused by items in the test area. The EMITP would need

to address antenna types, antenna locations, antenna polarizations and field measurement techniques. This test would probably need to be performed in an anechoic chamber.

For frequency hopping receivers, one possible approach is choose an f_c within the hop set and set up the signals sources as described above. The performance of the receiver could then be evaluated as the receiver hops. If the frequency hopping receiver has a mode of operation using just one fixed frequency, this mode should also be tested.

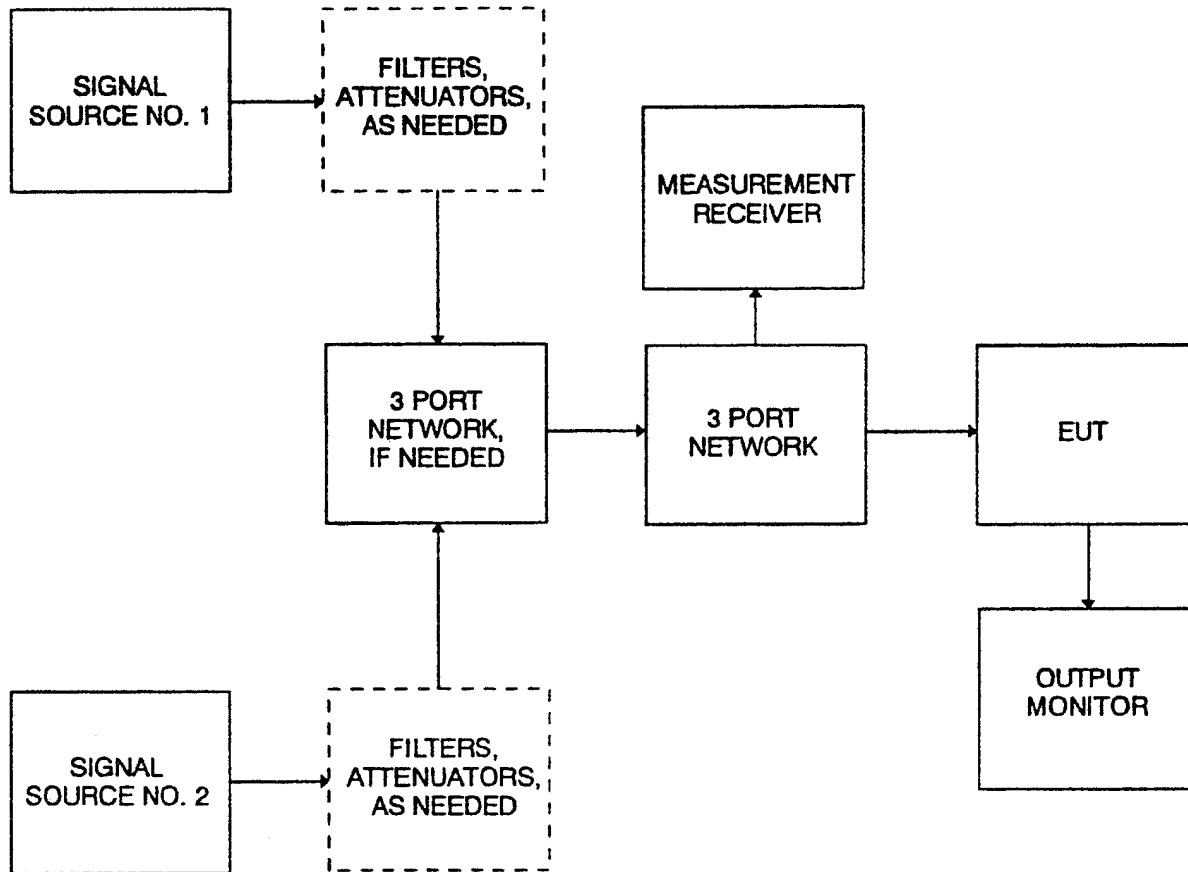


FIGURE A-7. CS105 General test setup.

It is important to verify that the signals appearing at the EUT antenna port are only the intended signals through the use of a measurement receiver as shown in Figure A-7. Damaged, corroded, and faulty components can cause signal distortion resulting in misleading results. Monitoring will also identify path losses caused by filters, attenuators, couplers, and cables.

Typical data for this test method for the EMITR are the sensitivity of the receiver, the levels of the signal sources,

frequency ranges swept, operating frequencies of the receivers, and frequencies and threshold levels associated with any responses.

TEST METHOD CS109:

This test method is used to verify the ability of the EUT to withstand lower frequency currents flowing in its structure. It is primarily intended to evaluate EUTs which include sensitive low frequency receivers such as sonar.

Electrical connection needs to be made to the external structure of the EUT and damage to the external finish should be minimized. Screws or protuberances at ground potential near the diagonal corners of the EUT should normally be used as test points. Connections should be made with clip or clamp type leads. If convenient test points are not available at the diagonal corners, a sharply pointed test probe should be used to penetrate the finish in place of the clip or clamp type lead.

TEST METHOD CS114:

This test method is used to verify the ability of the EUT to withstand RF signals present on interconnecting cables. This type of test is often considered as a bulk current test since current is the parameter measured. However, it is important to note that the test signal is inductively coupled and that Faraday's law predicts an induced voltage in a circuit loop with the resultant current flow and voltage distribution dependent on the various impedances present.

The loop circuit impedance measurement is strictly intended to provide engineering information to assist in analysis of results obtained for associated testing performed at the platform-level. A common technique used to assess platform-level performance is to illuminate the platform with low-level electromagnetic fields while monitoring induced current levels on cabling. The CS114 results can then be used to assess design margins. However, differences in circuit impedances between the laboratory and platform can cause perturbations between the laboratory and platform responses. The impedance information from the CS114 test assists in assessing these differences.

Earlier versions of MIL-STD-462 included a test method CS02 which specified capacitive coupling of a voltage onto individual power leads. As is the case for this test method, CS02 assessed the effect of voltages induced from electromagnetic fields. CS114 improves on CS02 by inducing levels on all wires at a connector interface simultaneously (common mode) which better simulates actual platform use. Also, a deficiency existed with

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CS02 since the RF signals were induced only on power leads. This test method is applicable to all EUT cabling.

An advantage of this type of conducted testing as compared to radiated susceptibility testing is that voltage and current levels can be more easily induced on the interfaces that are comparable to those present in installations. The physical dimensions of the EUT cabling in a test setup are often not large enough compared to the installation for efficient coupling at lower frequencies.

In the past, some platform-level problems on Navy aircraft could not be duplicated in the laboratory using the standard test methods in earlier versions of this standard. It was determined that differences between the aircraft installation and laboratory setups regarding the laboratory ground plane and avionics (aircraft electronics) mounting and electrical bonding practices were responsible. Most avionics are mounted in racks and on mounting brackets. At RF, the impedances to general aircraft structure for the various mounting schemes can be significantly different than they are with the avionics mounted on a laboratory ground plane. In the laboratory, it is not always possible to produce a reasonable simulation of the installation. A ground plane interference (GPI) test was developed to detect potential failures due to the higher impedance. In the GPI test, each enclosure of the EUT, in turn, is electrically isolated above the ground plane and a voltage is applied between the enclosure and the ground plane to simulate potential differences that may exist in the installation. Since CS114 provides similar common mode stresses at electrical interfaces as the GPI, the GPI is not included in this standard. However, the Navy may prefer to perform an additional susceptibility scan for aircraft applications with an inductor placed between the EUT enclosure and ground plane to more closely emulate the results of a GPI setup. The primary side of a typical CS101 injection transformer is considered to be an appropriate inductor.

CS114 has several advantages over the GPI as a general evaluation method. The GPI often results in significant current flow with little voltage developed at lower frequencies. CS114 is a controlled current test. A concern with the GPI test, which is not associated with CS114, is that the performance of interface filtering can be altered due to isolation of the enclosure from the ground plane. The results of CS114 are more useful since the controlled current can be compared with current levels present in the actual installation induced from fields. This technique has commonly been used in the past for certification of aircraft as safe to fly.

Testing is required on both entire power cables and power cables with the returns removed to evaluate common mode coupling

to configurations which may be present in different installations. In some installations, the power returns are routed with the high side wiring. In other installations, power returns are tied to system structure near the utilization equipment with system structure being used as the power return path.

A commonly used calibration fixture is shown in Figure A-8. Other designs are available. The top is removable to permit the lower frequency probes to physically fit. The calibration fixture can be scaled to accommodate larger injection probes.

NOTE: VERTICAL CROSS-SECTION AT CENTER OF FIXTURE SHOWN

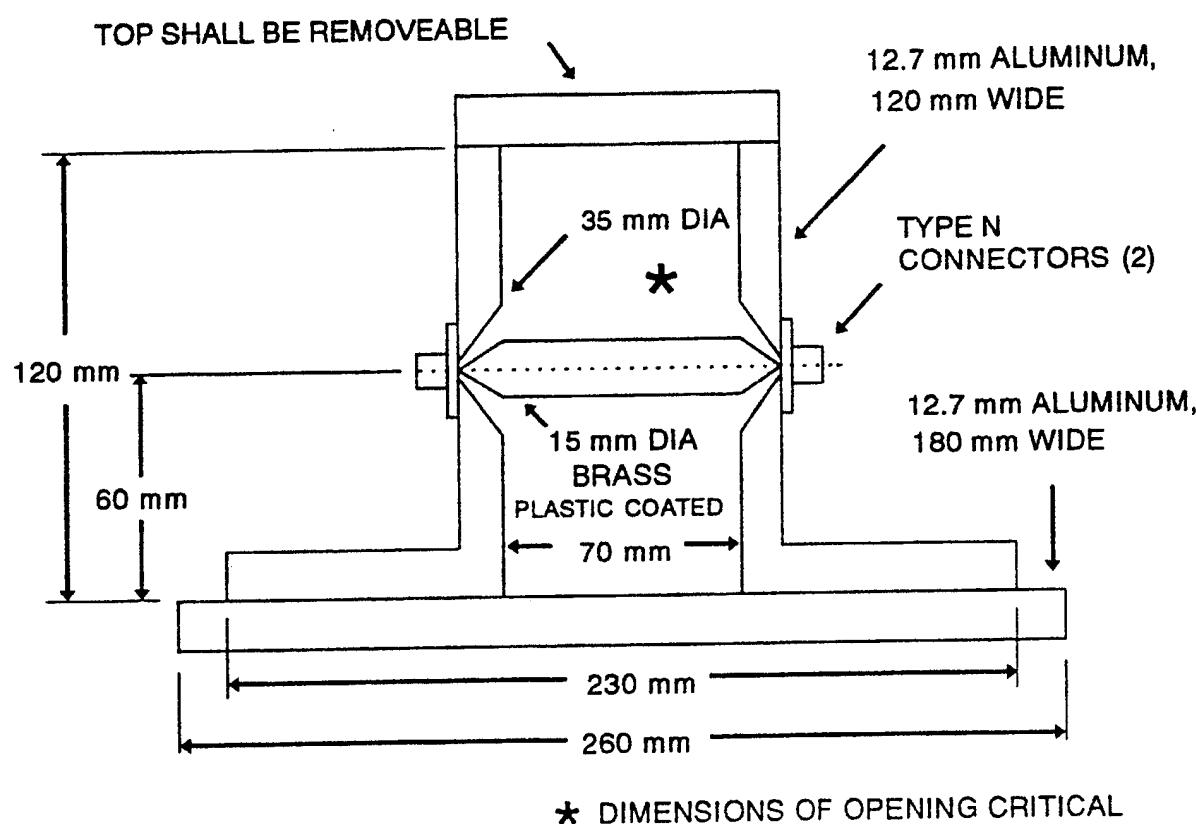


FIGURE A-8. Typical CS114 calibration fixture.

Figure A-9 shows insertion loss characteristics for typical injection probes. Insertion loss is the ratio of the power applied to the probe when installed in the calibration fixture and the power dissipated in one of the 50 ohm loads attached to the fixture. Lower insertion loss indicates more efficient

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coupling. Since power is equally divided between the two 50 ohm loads, the lowest possible loss is 3 dB. Flat characteristics with frequency are desirable to minimize the need for continuous adjustment of signal sources.

Care needs to be taken in normalizing readings to the amperes for one watt values specified in the test method since there is a square relationship between current and power. For example, if 0.001 watts of power results in 0.01 amperes of current in the calibration fixture, the current for one watt is equal to $(1 \text{ watt}/0.001 \text{ watts})^{1/2}(0.01 \text{ amperes}) = 0.32 \text{ amperes}$.

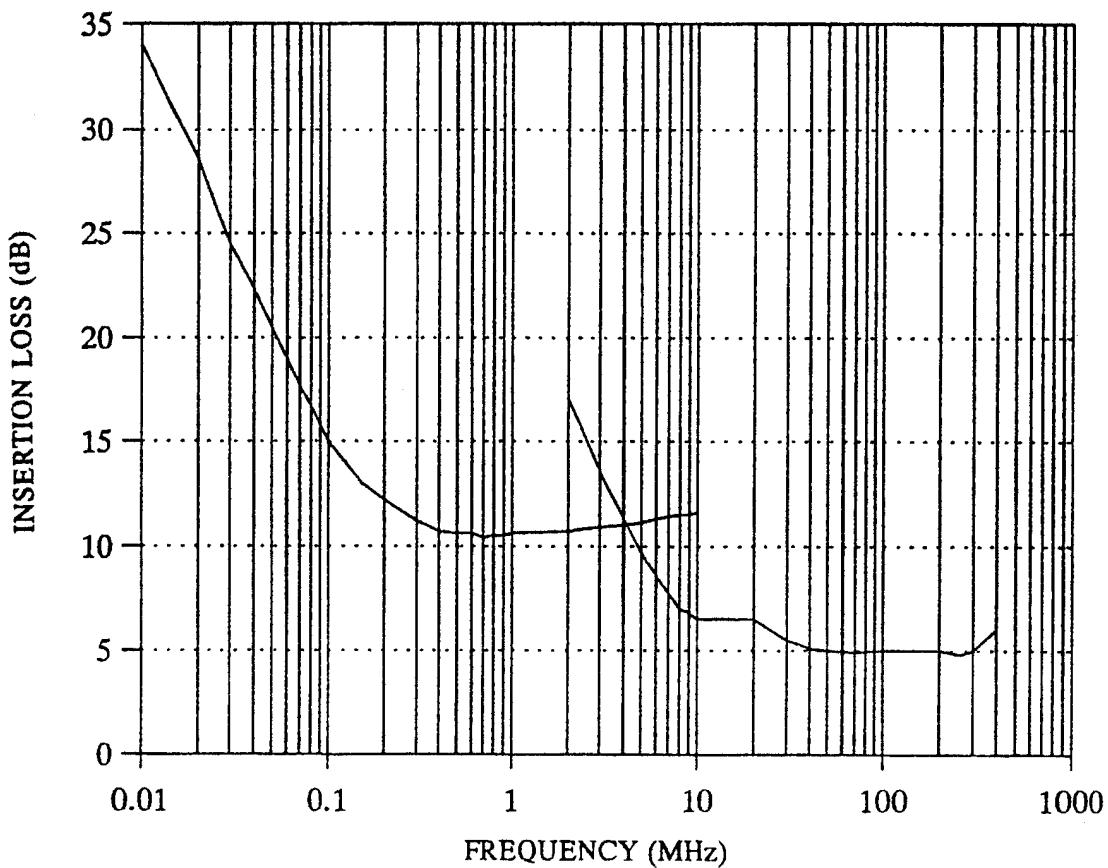


FIGURE A-9. Typical insertion loss of CS114 injection probes.

The loop circuit impedance evaluation for this test method is the same as that used in CS116. This data should be used, if available.

Techniques using network analyzers or spectrum analyzers with tracking generators can simplify the measurements for both paragraph 4.b calibration and paragraph 4.c EUT testing portions of the method. For example, the output signal can first be set to a predetermined value such as one milliwatt and the flatness of the signal with frequency can be separately verified through a direct connection to the receiver. With this same signal then applied to the directional coupler, the induced level in the calibration fixture can be directly plotted.

TEST METHOD CS115:

This test method is used to verify the ability of the EUT to withstand transient waveforms excited by fast rise time pulses coupled onto interconnecting cables. The excitation waveform from the generator is a trapezoidal pulse. The actual waveform on the interconnecting cable will be dependent on natural resonance conditions associated with the cable and EUT interface circuit parameters.

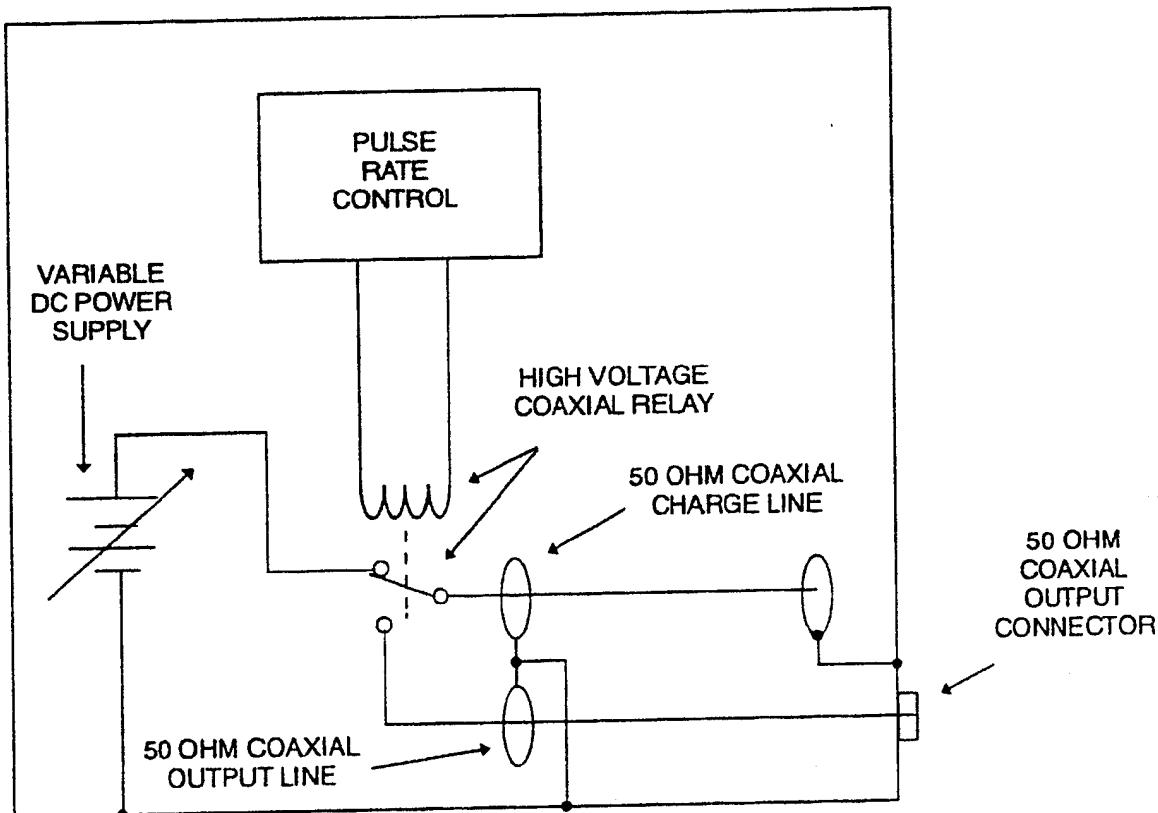


FIGURE A-10. Circuit diagram of CS115 pulse generator.

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A circuit diagram of the 50 ohm, charged line, pulse generator required by CS115 is shown in Figure A-10. Its operation is essentially the same as impulse generators used to calibrate measurement receivers except that the pulse width is much longer. A direct current power supply is used to charge the capacitance of an open-circuited 50 ohm coaxial line. The high voltage relay is then switched to the output coaxial line to produce the pulse. The pulse width is dependent upon the length of the charge line. The relay needs to have bounce-free contact operation.

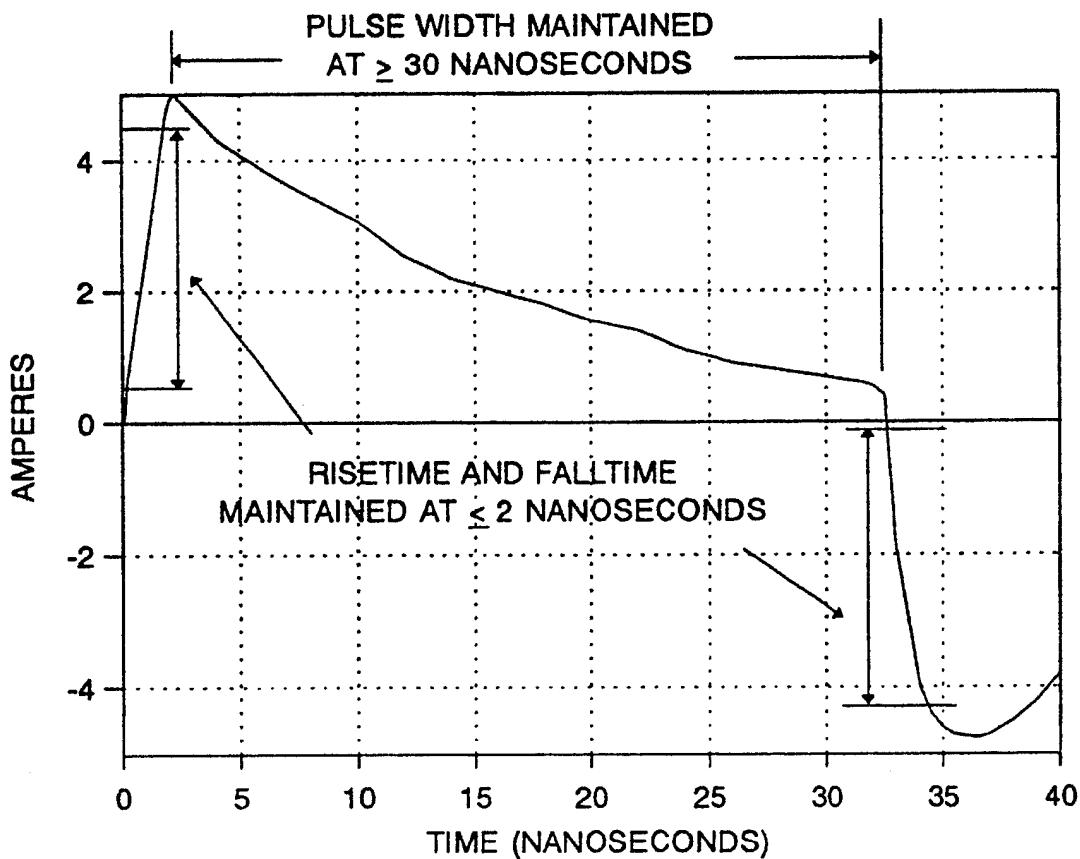


FIGURE A-11. Typical CS115 calibration fixture waveform.

Paragraph 4b(3) of CS115 requires verification that the rise time, fall time, and pulse width portions of the applied waveform are present in the observed waveform induced in the calibration fixture. Figure A-11 shows a typical waveform that will be present. Since the frequency response of injection probes falls off at lower frequencies, the trapezoidal pulse supplied to the probe sags in the middle portion of the pulse which is associated with the lower frequency content of the applied signal. The relevant parameters of the waveform are noted. It is critical

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that an injection probe be used with adequate response at higher frequencies to produce the required rise time and fall time characteristics.

As also specified in CS114, testing is required on both entire power cables and power cables with the returns removed to evaluate common mode coupling to configurations which may be present in different installations. In some installations, the power returns are routed with the high side wiring. In other installations, power returns are tied to system structure near the utilization equipment with system structure being used as the power return path.

Test method RS06 was previously included in MIL-STD-462. RS06 was a formalization of the "chattering relay" test used widely throughout the military aircraft industry. This method improves on RS06. The chattering relay has been found to be effective for determining upset conditions of equipment. The basic concept was to electrically connect the relay coil in series with a normally closed contact and allow the relay to continuously interrupt itself. The wire between the coil and contact was used to couple the transient onto EUT cables. The greatest concern with the chattering relay is that it does not produce a repeatable waveform since an arcing process is involved. The particular relay being used and the condition of its contact and coil mechanics play a large role. CS115 retains the most important characteristic of the chattering relay which is the fast rise time waveform and also has the important advantage of a consistent excitation waveform.

The same calibration fixture used for CS114 can be used for this test method. An available design is shown in Figure A-8.

TEST METHOD CS116:

This test method is used to verify the ability of the EUT to withstand damped sine transients induced onto interconnecting cables. In contrast to CS115 which excites natural resonances, the intent of this test is to control the waveform as a damped sine. Damped sine waveforms (sometimes complex combinations) are a common occurrence on platforms from both external stimuli such as lightning and electromagnetic pulse and from platform electrical switching phenomena. Waveforms appearing on cables can be due to the cable itself resonating or to voltage and current drives resulting from other resonances on the platform. Wide frequency coverage is included to account for a wide range of conditions.

MIL-STD-462 previously included test methods CS10, CS11, CS12, and CS13 which addressed various types of damped sine testing on both cables and individual circuits or connector pins.

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This test method is a single replacement for all those methods. CS116 addresses testing of cables (interconnecting including power) and individual power leads. The common mode cable portion of the test is the best simulation of the type of condition present on platforms from electromagnetic field excitation. The individual power lead test addresses differential type signals present on platforms from switching functions occurring in the power system.

As necessary, the test can be applied in a straightforward manner to wires on individual pins on an EUT connector or to individual circuits (twisted pairs, coaxial cables, and so forth).

Since the quality factor (Q) of the damped sine signal results in both positive and negative peaks of significant value regardless of the polarity of the first peak, there is no requirement to switch the polarity of the injected signal.

The common mode injection technique used in this method and other methods such as CS114 is a partial simulation of the actual coupling mechanism on platforms. The magnetic field in the injection device is present at the physical location of the core of the injection device. In the platform, the electromagnetic field will be distributed in space. The injection probe induces a voltage in the circuit loops present with the voltage dropping and current flowing based on impedances present in the loop. There is a complex coupling relationship among the various individual circuits within the cable bundle. The injection probe is required to be close to the EUT connector for standardization reasons to minimize variations particularly for higher frequencies where the shorter wavelengths could affect current distribution.

A loop circuit impedance evaluation is required to identify impedance maximum and minimum. Voltage and current, respectively, will be maximized during testing at the associated frequencies, thus providing maximum stress on the EUT. This procedure is done to ensure performance of the EUT in the installation when worst-case coupling occurs. The loop circuit impedance evaluation is also required by CS114 and that data should be used when available.

TEST METHOD RE101:

This test method is used to measure magnetic field emissions radiated from the EUT and associated cabling. A 13.3 cm loop is specified for the test.

Two measurement distances of 7 and 50 centimeters are specified to allow for evaluation of potential impacts in the

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actual installation. There may be instances where potentially sensitive equipment is a sufficient distance from the point of emissions that a 50 centimeter control distance is adequate.

If the maximum level is always observed on one face or on one cable at all frequencies, then data only needs to be recorded for that face or cable.

Typical points of magnetic field emissions leakage from EUT enclosures and cables are cable shield terminations, CRT yokes, transformers and switching power supplies.

A possible alternative measurement tool in this frequency range is wave analyzer using a Fast Fourier Transform algorithm. Use of this type of instrumentation requires specific approval by the procuring activity.

TEST METHOD RE102:

This test method is used to measure electric field emissions radiating from the EUT and associated cabling.

Specific antennas are required by this method for standardization reasons. The intent is to obtain consistent results between different test facilities.

In order for adequate signal levels to be available to drive the measurement receivers, physically large antennas are necessary. Due to shielded room measurements, the antennas are required to be relatively close to the EUT, and the radiated field is not uniform across the antenna aperture. For electric field measurements below several hundred megahertz, the antennas do not measure the true electric field.

The 104 centimeter rod antenna has a theoretical electrical length of 0.5 meters and is considered to be a short monopole with an infinite ground plane. It would produce the true electric field if a sufficiently large counterpoise were used to form an image of the rod in the ground plane. However, there is not adequate room. The requirement to bond the counterpoise to the shielded room or earth ground, as applicable, is intended to improve its performance as a ground plane. The biconical and double ridged horn antennas are calibrated using far-field assumptions at a 1 meter distance. This technique produces standardized readings. However, the true electric field is obtained only above approximately 1 GHz where a far field condition exists for practical purposes.

Antenna factors are determined using the procedures of SAE ARP-958. They are used to convert the voltage at the measurement receiver to the field strength at the antenna. Any RF cable loss

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and attenuator values must be added to determine the total correction to be applied.

Previous versions of this standard specified conical log spiral antennas. These antennas were convenient since they did not need to be rotated to measure both polarizations of the radiated field. The double ridged horn is considered to be better for standardization for several reasons. At some frequencies, the antenna pattern of the conical log spiral is not centered on the antenna axis. The double ridged horn does not have this problem. The circular polarization of the conical log spiral creates confusion in its proper application. Electric fields from EUTs would rarely be circularly polarized. Therefore, questions are raised concerning the need for 3 dB correction factors to account for linearly polarized signals. The same issue is present when spiral conical antennas are used for radiated susceptibility testing. If a second spiral conical is used to calibrate the field correctly for a circularly polarized wave, the question arises whether a 3 dB higher field should be used since the EUT will respond more readily to linearly polarized fields of the same magnitude.

Other linearly polarized antennas such as log periodic antennas are not to be used. It is recognized that these types of antennas have sometimes been used in the past; however, they will not necessarily produce the same results as the double ridged horn because of field variations across the antenna apertures and far field/near field issues. Uniform use of the double ridge horn is required for standardization purposes to obtain consistent results among different test facilities.

Normally, a horn antenna is used above 10 GHz. Caution should be exercised to select antennas which have patterns with broad beamwidths.

The stub radiator required by the method is simply a short wire (approximately 10 centimeters) connected to the center conductor of a coaxial cable which protrudes from the end of the cable.

There are two different mounting schemes for baluns of available 104 centimeter rod antennas with respect to the counterpoise. Some are designed to be mounted underneath the counterpoise while others are designed for top mounting. Either technique is acceptable provided the desired 0.5 meter electrical length is achieved with the mounting scheme.

The antenna positioning requirements in this method are based on likely points of radiation and antenna patterns. At frequencies below several hundred MHz, radiation is most likely to originate from EUT cabling. The 104 centimeter rod and

biconical antennas have wide pattern coverage. The equation in Figure RE102-3 is based on the rod and biconical being placed at least every 3 meters along the test setup boundary. The double ridge horns have narrower beamwidths. However, the shorter wavelengths above 200 MHz will result in radiation from EUT apertures and portions of cabling close to EUT interfaces. The requirements for antenna positioning above 200 MHz are based on including EUT apertures and lengths of cabling at least one quarter wavelength.

All the specified antennas are linearly polarized. Above 30 MHz, measurements must be performed to measure both horizontal and vertical components of the radiated field. Measurements with the 104 centimeter rod are performed only for vertical polarization. This antenna configuration is not readily adapted for horizontal measurements.

For equipment or subsystems which have enclosures or cabling in various parts of a platform, data may need to be taken for more than one configuration. For example, in an aircraft installation where a pod is located outside of aircraft structure and its associated cabling is internal to structure, two different MIL-STD-461 limits may be applicable. Different sets of data may need to be generated to isolate emissions from the pod housing and from cabling. The different emissions of the equipment would need to be protected with appropriate shielding during each evaluation.

TEST METHOD RE103:

This test method is used to measure spurious and harmonic outputs of transmitters in the far field. It is a radiated technique and therefore includes the antenna system characteristics.

Since the test method measures emissions radiating from an antenna connected to a controlled impedance, shielded, transmission line, the measurement results should be largely independent of the test setup configuration. Therefore, it is not necessary to maintain the basic test set described in the main body of this standard.

The test methodology is laborious and will require a large open area to meet antenna separation distances. Equations in the test method specify minimum acceptable antenna separations based on antenna size and operating frequency of the EUT. Antenna pattern searches in both azimuth and elevation are required at the spurious and harmonic emissions to maximize the level of the detected signal and account for antenna characteristics.

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Sensitivity of the measurement system may need enhancement by use of preamplifiers and the entire test needs to be coordinated with local frequency allocation authorities. All recorded data has to be corrected for space loss and antenna gain before comparisons to the limit.

As shown in Figures RE103-1 and RE103-2, shielding might be necessary around the measurement system and associated RF components to prevent the generation of spurious responses in the measurement receiver. The need for such shielding can be verified by comparing measurement runs with the input connector of the measurement receiver terminated in its characteristic impedance and with the EUT in both transmitting and stand-by modes or with the EUT turned off. Also, the receiving or transmit antenna may be replaced with a dummy load to determine if any significant effects are occurring through cable coupling.

The RF cable from the receive antenna to the measurement receiver should be kept as short as possible to minimize signal loss and signal pick-up.

The band-rejection filters and networks shown in Figures RE103-1 and RE103-2 are needed to block the transmitter fundamental and thus reduce the tendency of the measurement receiver to generate spurious responses or exhibit suppression effects because of the presence of strong out-of-band signals. These rejection networks and filters require calibration over the frequency range of test.

Some caution needs to be exercised in applying Table II of the main body of this standard. In paragraph 4d(4) of the test method, a power monitor is used to measure the output power of the EUT. In conjunction with the antenna gain, this value is used to calculate the effective radiated power (ERP) of the equipment. In paragraph 4d(5) of the test method, the measurement receiver is used to measure the power from a receiving antenna. This result is also used to calculate an ERP. For the 2 measurements to be comparable, the measurement receiver bandwidth needs to be sufficiently large to include at least 90% of the power of the signal present at the tuned frequency. If the bandwidth in Table II of the main body of the standard is not appropriate, a suitable measurement receiver bandwidth should be proposed in the EMITP.

TEST METHOD RS101:

This test method is used to verify the ability of the EUT to withstand lower frequency magnetic fields. This test is primarily intended to evaluate low frequency receivers which operate within the frequency range of the test.

Laboratory tests have been performed to assess the possibility of using the 13.3 centimeter loop sensor specified in Test Method RE101 instead of the 4 centimeter loop sensor in this test method to verify the radiated field. The testing revealed that the 13.3 centimeter loop sensor did not provide the desired result due to variation of the radiated field over the area of the loop sensor. Due to its smaller size, the 4 centimeter loop sensor provides an accurate measure of the field near the axis of the radiating loop.

TEST METHOD RS103:

This test method is used to verify that the EUT does not respond to radiated electric fields.

Test facilities are permitted to select appropriate electric field generating apparatus. Any electric field generating device such as antenna, long wire, TEM cell, reverberating chamber (when approved by the procuring activity) or parallel strip line capable of generating the required electric field may be used. Fields should be maintained as uniform as possible over the test setup boundary. Above 30 MHz, both horizontally and vertically polarized fields must be generated. This requirement may limit the use of certain types of apparatus. Only vertically polarized measurements are required below 30 MHz due to the difficulty of orienting available test equipment for horizontal measurements.

TEM cells, reverberating chambers or other unconventional techniques require approval since they may be unsuitable for certain applications. Procuring agencies must consider a number of issues in deciding whether to allow the use of these alternative techniques for a particular procurement. Issues relating to TEM cells and reverberation chambers are discussed below.

TEM cells produce relatively uniform fields at modest power input levels. TEM cells are shielded volumes with a center plate which is driven by a signal source. A plane wave is propagated between the center plate and the upper and lower surfaces. There are several concerns with TEM cells. Only vertically polarized electric fields are produced. While some EUT enclosures can be placed in several orientations for assessment, proper evaluation of coupling to any electrical interface cabling is difficult. There is usually no convenient method to expose the cabling to electric fields aligned with the cabling. Since the EUT is usually placed on the center plate (which is the driven element), the requirements in the general portion of this standard for use of ground planes cannot be implemented. Space limitations are a potential problem because of the 2 meter required lengths of cabling. Multiple EUT enclosures can exacerbate this situation.

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Reverberating chambers, using mode stirred techniques, have been popular for performing shielded effectiveness evaluations and, in some cases, have been used for radiated susceptibility testing of equipment and subsystems. The concept used in reverberating chambers is to excite available electromagnetic wave propagation modes to set up variable standing wave patterns in the chamber. A transmit antenna is used to launch a electromagnetic wave. An irregular shaped paddle wheel (mode stirrer) is rotated to excite the different modes and modify the standing wave pattern in the chamber. Any physical location in the chamber will achieve same peak field strength at some position of the paddle wheel.

Reverberation chambers have the advantage of producing relatively higher fields than other techniques for a particular power input. Also, the orientation of EUT enclosures is less critical since the all portions of the EUT will be exposed to the same peak field at some paddle wheel position. The performance of a particular reverberation chamber is dependent upon a number of factors including dimensions, Q of the chamber, number of available propagation modes, and frequency range of use.

However, there are some concerns. The field polarization and distribution with respect to the EUT layout are generally unknown at a point in time. If a problem is noted, the point of entry into the EUT may not be apparent. Since paragraph 4.10.4.2 of the main body of the standard requires a one second dwell time to allow the EUT to respond to the susceptibility signal, the paddle wheel must be maintained at each position for one second. If the paddle wheel has 100 positions, 100 seconds is required for a particular tuned frequency. The maximum step sizes listed in Table III of the main body are based on assumed Q values that could be present in the EUT and associated cabling. If the signal source is stepped in increments of the indicated sizes, test times could become excessively long. For this example, test time would be approximately 100 times greater than using a conventional radiating antenna technique. The procuring activity could approve a change to the step size or dwell time requirements taking on some risk that an EUT response would be missed at some frequencies. The performance of a particular chamber must be reviewed to determine the criticality of these concerns.

Reverberation chambers are sometimes treated as a good tool to determine potential problem frequencies with conventional antenna methods being used to evaluate areas of concern.

Monitoring requirements emphasize measuring true electric field. While emission testing for radiated electric fields does not always measure true electric field, sensors with adequate sensitivity are available for field levels generated for

susceptibility testing. Physically small and electrically short sensors are required so that the electric field does not vary substantially over the pickup element resulting in the measurement of a localized field. Broadband sensors not requiring tuning are available.

The use of more than one sensor is acceptable provided all sensors are within the beamwidth of the transmit antenna. The effective field is determined by taking the average of the readings. For example, if the readings of three sensors are 30, 22, and 35 volts/meter, the effective electric field level is $(30 + 22 + 35)/3 = 29$ volts/meter.

Different sensors may use various techniques to measure the field. At frequencies where far-field conditions do not exist, sensors must be selected which have electric field sensing elements. Sensors which detect magnetic field or power density and convert to electric field are not acceptable. Under far-field conditions, all sensors will produce the same result. Correction factors must be applied for modulated test signals for equivalent peak detection as discussed under paragraph 4.9.1. A typical method for determining the correction factor for these sensors is as follows:

1. Generate a field at a selected frequency using an unmodulated source.
2. Adjust the field to obtain a reading on the sensor display near full scale and note the value.
3. Modulate the field as required (normally 1 kHz pulse, 50% duty cycle) and ensure the field has the same peak value. A measurement receiver with the peak detector selected and receiving antenna can be used to make this determination.
4. Note the reading on the sensor display.
5. Divide the first reading by the second reading to determine the correction factor (Subtract the two readings if the field is displayed in terms of dB).
6. Repeat the procedure at several frequencies to verify the consistency of the technique.

Above 1 GHz, radiated fields usually exhibit far-field characteristics for test purposes due to the size of typical transmit antennas, antenna patterns, and distances to the EUT. Therefore, a double ridged horn together with a measurement receiver will provide true electric field. Similarly, the particular sensing element in an isotropic sensor is not

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critical, and acceptable conversions to electric field can be made.

For equipment or subsystems which have enclosures or cabling in various parts of a platform, data may need to be taken for more than one configuration. For example, in an aircraft installation where a pod is located outside of aircraft structure and its associated cabling is internal to structure, two different MIL-STD-461 limits may be applicable. Different sets of data may need to be generated to evaluate potential pod susceptibility due to coupling through the housing versus coupling from cabling. The non-relevant portion of the equipment would need to be protected with appropriate shielding.

TEST METHOD RS105:

This test method is used to verify the ability of EUT to withstand the fast rise time, free-field, transient conditions of electromagnetic pulse (EMP). It is intended to be used for equipment enclosures which are directly exposed to the incident field outside of platform structure. EUT cabling is not evaluated as part of this test. Effects due to cable coupling are tested under CS116. To protect the EUT and monitoring and simulation equipment, all cabling should be treated with overall shielding.

The EMP field is simulated in the laboratory using bounded wave TEM radiators such as TEM cells and parallel plate transmission lines. To ensure that the EUT does not significantly distort the field in the test volume, the EUT dimensions should be no more than a third of the dimension between the sides of the simulator. In these simulators the electric field is perpendicular to the surfaces of the radiator. Since the polarization of the incident EMP field in the installation is not known, the EUT must be tested in all orthogonal axes.

Since this test may cause damage to the EUT, it is advisable to first test at 50% of the specified limit, with two pulses, and then increase the amplitude slowly until the specified limit is reached.

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
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I RECOMMEND A CHANGE:

1. DOCUMENT NUMBER

2. DOCUMENT DATE (YYMMDD)

3. DOCUMENT TITLE

4. NATURE OF CHANGE (Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)

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NOTICE OF
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METRIC

MIL-STD-462D
NOTICE 1
10 April 1995

MILITARY STANDARD

MEASUREMENT OF
ELECTROMAGNETIC INTERFERENCE
CHARACTERISTICS

TO ALL HOLDERS OF MIL-STD-462D:

1. THE FOLLOWING PAGES OF MIL-STD-462D HAVE BEEN REVISED AND SUPERSEDE THE PAGES LISTED:

NEW PAGE	DATE	SUPERSEDED PAGE	DATE
1	11 January 1993	-	REPRINTED WITHOUT CHANGE
2	10 April 1995	2	11 January 1993
3	10 April 1995	3	11 January 1993
4	10 April 1995	4	11 January 1993
15	10 April 1995	15	11 January 1993
16	11 January 1993	-	REPRINTED WITHOUT CHANGE
A-5	11 January 1993	-	REPRINTED WITHOUT CHANGE
A-6	10 April 1995	A-6	11 January 1993
A-7	10 April 1995	A-7	11 January 1993
A-8	10 April 1995	A-8	11 January 1993
A-41	11 January 1993	-	REPRINTED WITHOUT CHANGE
A-42	10 April 1995	A-42	11 January 1993

2. This change notice removes MIL-STD-45662 from this standard.
3. RETAIN THIS NOTICE AND INSERT BEFORE TABLE OF CONTENTS.
4. Holders of MIL-STD-462D will verify that page changes and additions indicated above have been entered. This notice page will be retained as a check sheet. This issuance, together with appended pages, is a separate publication. Each notice is to be retained by stocking points until the military standard is completely revised or cancelled.

Custodians:
Army - CR
Navy - EC

Preparing activity:
Air Force - 11

Project Nr. EMCS-0134

AMSC: N/A

AREA: EMCS

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

1. SCOPE

1.1 Purpose. This standard establishes general techniques for use in the measurement and determination of the electromagnetic emission and susceptibility characteristics of electronic, electrical, and electromechanical equipment and subsystems designed or procured for use by activities and agencies of the Department of the Defense.

1.2 Application. The testing techniques of this standard are used to obtain data for determination of compliance with the specified MIL-STD-461 requirements. The test methods contained in this document shall be adapted by the testing activity for each application. The adapted test methods shall be documented in the Electromagnetic Interference Test Procedures (EMITP) required by MIL-STD-461.

1.3 Emission and susceptibility designations. The test methods contained in this standard are designated in accordance with an alpha-numeric coding system. Each method is identified by a two letter combination followed by a three digit number. The number is for reference purposes only. The meaning of the individual letters are as follows:

C = Conducted
R = Radiated
E = Emissions
S = Susceptibility

- a. Conducted emissions tests are designated by "CE---".
- b. Radiated emissions tests are designated by "RE---".
- c. Conducted susceptibility tests are designated by "CS---".
- d. Radiated susceptibility test are designated by "RS---".
- e. "---" = numerical order of test from 101 to 199.

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2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.2 Specifications, standards, and handbooks. The following document forms a part of this document to the extent specified herein. Unless otherwise specified, the issue of this document is the one listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement(s) thereto, cited in the solicitation.

STANDARDS

MILITARY

- MIL-STD-461 - Requirements for the Control
of Electromagnetic
Interference Emissions and
Susceptibility

(Copies of federal and military specifications, standards, and handbooks are available from the Department of Defense Single Source Stock Point, 700 Robbins Avenue, Building 4D, Philadelphia, Pennsylvania 19111-5094.)

2.2 Non-Government documents. The following non-government documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents which are DoD adopted are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

- ANSI/IEEE 268 - Standard Metric Practice
(DoD Adopted)

- ANSI C63.2 - Standard for Instrumentation -
Electromagnetic Noise and Field
Strength, 10 kHz to 40 GHz -
Specifications

Supersedes page 2 dated 11 January 1993.

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AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) - Continued

ANSI C63.4

- Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

ANSI C63.14

- Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD)

ANSI C95.1

- Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz - 100 GHz

ANSI/NCSL Z540-1 - General Requirements for Calibration Laboratories and Measuring and Test Equipment

ISO 10012-1

- Quality Assurance Requirements for Measuring Equipment

(DoD activities may obtain copies from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia PA 19111-5094. Other Government agencies and the private sector may address application for copies to the American National Standards Institute, 11 West 42nd Street, New York, New York 10036 [Telephone: 212-642-4900 or FAX: 212-398-0023]; or the Institute of Electrical and Electronics Engineers, Incorporated (IEEE), 445 Hoes Lane, Piscataway, New Jersey 08855-1331 [Telephone: 1-800-701-4333 or FAX: 908-981-9667].)

Supersedes page 3 dated 11 January 1993.

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NOTICE 1

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 380

- Standard for Metric Practice
(DoD Adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103-1187 [Telephone: 215-299-5585 or FAX: 215-977-9679].)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

ARP 958

- Electromagnetic Interference
Measurement Antennas; Standard
Calibration Requirements and
Methods

(Application for copies should be addressed to the Society of Automotive Engineers, Incorporated, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096 [Telephone: 412-776-4841 or FAX: 412-776-5760].)

Supersedes page 4 dated 11 January 1993.

- d. Record this level, frequency range of occurrence, frequency and level of greatest susceptibility, and other test parameters, as applicable.

4.11 Calibration of measuring equipment and antennas. Test equipment and accessories required for measurement in accordance with this standard shall be calibrated in accordance with ANSI/NCSL Z540-1: "General Requirements for Calibration Laboratories and Measuring and Test Equipment", ISO 10012-1: "Quality Assurance Requirements for Measuring Equipment", or under an approved calibration program traceable to the NIST. In particular, measurement antennas, current probes, field sensors, and other devices used in the measurement loop shall be calibrated at least every two years unless otherwise specified by the procuring activity, or when damage is apparent. Antenna factors and current probe transfer impedances shall be determined on an individual basis for each device.

4.11.1 Measurement of system test. At the start of each emission test, the complete test system (including measurement receivers, cables, attenuators, couplers, and so forth) shall be verified by injecting a known signal, as stated in the individual test method, while monitoring system output for the proper indication.

4.12 Antenna factors. Factors for electric field test antennas shall be determined in accordance with SAE ARP-958: "Electromagnetic Interference Measurement Antennas; Standard Calibration Requirements and Methods".

Supersedes page 15 dated 11 January 1993.

5. MEASUREMENT PROCEDURES

This section contains the measurement procedures to be used in determining compliance with the emission and susceptibility requirements of MIL-STD-461. The test procedures are applicable for the entire specified frequency range; however, certain equipment or classes of equipment may not require testing throughout the complete measurement frequency range. These modifications are specified in MIL-STD-461. Table IV is an index of measurement procedures by method number and title.

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10. GENERAL

10.1 Scope. This appendix provides background information for each requirement in the main body of the standard. The information includes rationale for the test requirements and guidance for application of the requirements. This information should help users understand the intent behind the test requirements and adapt them in the Electromagnetic Interference Test procedures (EMITP) as necessary for particular applications. This appendix is provided for guidance purposes and, as such, should not be interpreted as providing contractual requirements.

10.2 Structure. This appendix follows the same general format as the main body of the standard. A "DISCUSSION" paragraph is provided for each requirement contained in the standard.

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20. APPLICABLE DOCUMENTS

20.1 Government documents.

20.1.2 Specifications, standards, and handbooks. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issue of this document is the one listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement(s) thereto, cited in the solicitation.

STANDARDS

MILITARY

- | | |
|-------------|---|
| MIL-STD-220 | - Method of Insertion Loss Measurement |
| MIL-STD-285 | - Attenuation measurements for Enclosures, Electromagnetic Shielding, for Electronic Test Purposes, Method of |
| MIL-STD-461 | - Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility |

(Copies of federal and military specifications, standards, and handbooks are available from the Department of Defense Single Source Stock Point, 700 Robbins Avenue, Building 4D, Philadelphia, Pennsylvania 19111-5094.)

20.2 Non-Government documents. The following non-government documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents which are DoD adopted are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation.

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AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

- ANSI/IEEE 268 - Standard Metric Practice
(DoD Adopted)
- ANSI C63.2 - Standard for Instrumentation -
Electromagnetic Noise and Field
Strength, 10 kHz to 40 GHz -
Specifications
- ANSI C63.4 - Methods of Measurement of Radio-
Noise Emissions from Low-Voltage
Electrical and Electronic
Equipment in the Range of
9 kHz to 40 GHz
- ANSI C63.14 - Standard Dictionary for
Technologies of Electromagnetic
Compatibility (EMC),
Electromagnetic Pulse (EMP),
and Electrostatic Discharge
(ESD)
- ANSI C95.1 - Safety Levels with Respect to Human
Exposure to Radio Frequency
Electromagnetic Fields,
300 kHz - 100 GHz
- ANSI/NCSL Z540-1 - General Requirements for Calibration
Laboratories and Measuring and
Test Equipment
- ISO 10012-1 - Quality Assurance Requirements for
Measuring Equipment

(DoD activities may obtain copies from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia PA 19111-5094. Other Government agencies and the private sector may address application for copies to the American National Standards Institute, 11 West 42nd Street, New York, New York 10036 [Telephone: 212-642-4900 or FAX: 212-398-0023]; or the Institute of Electrical and Electronics Engineers, Incorporated (IEEE), 445 Hoes Lane, Piscataway, New Jersey 08855-1331 [Telephone: 1-800-701-4333 or FAX: 908-981-9667].)

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AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 380 - Standard for Metric Practice
(DoD Adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103-1187 [Telephone: 215-299-5585 or FAX: 215-977-9679].)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

National Electrical Code

(Application for copies should be addressed to the National Fire Protection Association, One Batterymarch Park, P.O. Box 9101, Quincy MA 02269-9990 [Telephone: 617-770-3000 or FAX: 617-770-0700].)

RADIO TECHNICAL COMMISSION FOR AERONAUTICS (NFPA)

DO-160 - Environmental Conditions and
Test Conditions for Airborne
Equipment

(Application for copies should be addressed to the Radio Technical Commission for Aeronautics Secretariat, One McPherson Square, Suite 500, 1425 K Street, NW, Washington DC 20005.)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

ARP 958 - Electromagnetic Interference
Measurement Antennas; Standard
Calibration Requirements and
Methods

(Application for copies should be addressed to the Society of Automotive Engineers, Incorporated, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096 [Telephone: 412-776-4841 or FAX: 412-776-5760].)

Supersedes page A-8 dated 11 January 1993.

at 1 GHz with a bandwidth of 100 kHz has a Q of 1 GHz/100 kHz or 10,000.

Automatic leveling used to stabilize the amplitude of a test signal for stepped scans may require longer dwell times than one second at discrete frequencies. The signal will take time to settle and any EUT responses during the leveling process should be ignored.

40.10.4.2 (4.10.4.2.) Modulation of susceptibility signals. Susceptibility test signals above 10 kHz shall be pulse modulated at a 1 kHz rate with a 50% duty cycle unless otherwise specified in an individual test method of this standard.

DISCUSSION: Modulation is usually the effect which degrades EUT performance. The wavelengths of the RF signal cause efficient coupling to electrical cables and through apertures (at higher frequencies). Nonlinearities in the circuit elements detect the modulation on the carrier. The circuits may then respond to the modulation depending upon detected levels, circuit bandpass characteristics, and processing features.

Pulse modulation at a 1 kHz rate, 50% duty cycle, (alternately termed 1 kHz square wave modulation) is specified for several reasons. One kHz is within the bandpass of most analog circuits such as audio or video. The fast rise and fall times of the pulse causes the signal to have significant harmonic content high in frequency and can be detrimental to digital circuits. Response of electronics has been associated with energy present and a square wave results in high average power. The modulation encompasses many signal modulations encountered in actual use. The square wave is a severe form of amplitude modulation used in communications and broadcasting. It also is a high duty cycle form of pulse modulation representative of radars.

Previous versions of MIL-STD-461 required that the worst case modulation for the EUT be used. Worst case modulation usually was not known or determined. Also, worst case modulation may not be related to modulations seen in actual use or may be very specialized. The most typical modulations used below approximately 400 MHz have been amplitude modulation at either 400 or 1000 Hz (30 to 80%) or pulse modulation, 50% duty cycle, at 400 or 1000 Hz. These same modulations have been used above 400 MHz together with pulse modulation at various pulse widths and pulse repetition frequencies. Continuous wave (CW - no modulation) has also occasionally been used. CW typically produces a detected DC level in the circuitry and affects certain types of circuits. In general, experience has shown that modulation is more likely to cause degradation. CW should be included as an additional requirement when assessing circuits.

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which respond only to heat such as electroexplosive devices. CW should not normally be used as the only condition.

40.10.4.3 (4.10.4.3) Thresholds of susceptibility. When susceptibility indications are noted in EUT operation, a threshold level shall be determined where the susceptible condition is no longer present. Thresholds of susceptibility shall be determined as follows:

- a. When a susceptibility condition exists, reduce the interference signal until the EUT recovers.
- b. Reduce the interference signal by an additional 6 dB.
- c. Gradually increase the interference signal until the susceptibility condition reoccurs. The resulting level is the threshold of susceptibility.
- d. Record this level, frequency range of occurrence, frequency and test level of greatest susceptibility, and other test parameters, as applicable.

DISCUSSION: It is usually necessary to test at levels above MIL-STD-461 requirements to ensure that the test signal is at least at the required level. Determination of a threshold of susceptibility is necessary when degradation is present to assess whether requirements are met. This information should be included in the EMITR. Threshold levels below MIL-STD-461 requirements are unacceptable.

The specified steps to determine thresholds of susceptibility standardize a particular technique. An alternative method sometimes utilized in the past was to use the value of the applied signal where the EUT recovers (step a above) as the threshold. Hysteresis type effects are often present where different values are obtained for the two methods.

40.11 (4.11) Calibration of measuring equipment and antennas. Test equipment and accessories required for measurement in accordance with this standard shall be calibrated in accordance with ANSI/NCSL Z540-1: "General Requirements for Calibration Laboratories and Measuring and Test Equipment", ISO 10012-1: "Quality Assurance Requirements for Measuring Equipment", or under an approved calibration program traceable to the NIST. In particular, measurement antennas, current probes, field sensors, and other devices used in the measurement loop shall be calibrated at least every 2 years unless otherwise specified by the procuring activity, or when damage is apparent. Antenna factors and current probe transfer impedances shall be determined on an individual basis for each device.

DISCUSSION: Calibration is typically required for any measurement device whose characteristics are not verified through

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